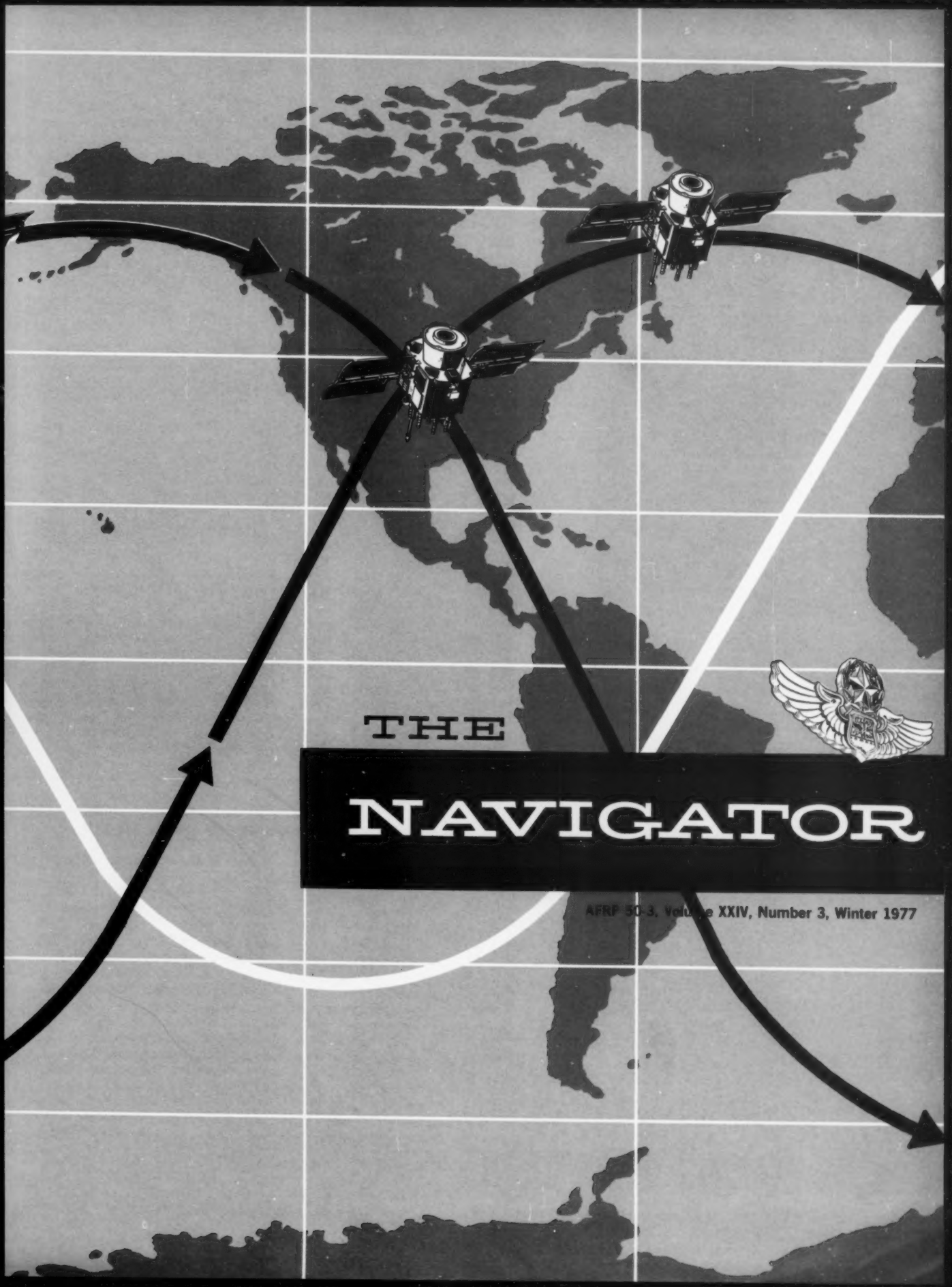

THE NAVIGATOR

AFRP 50-3, Volume XXIV, Number 3, Winter 1977

NAV OF NOTE

Air Force now has a navigator commanding a Tactical Air Command flying organization.

Colonel James E. Witzel, a navigator, is presently commanding the 432d Tactical Drone Group at Davis-Monthan AFB, Arizona. The 432 TDG has only been an entity since 1 Jul 76, when the fledgling unit was born through consolidation of the Remotely Piloted Vehicle (RPV/drone) assets within TAC and SAC. Colonel Witzel joined the 432d in August 1976 from a previous job as Director of Force Integration Studies, USAF Tactical Air Warfare Center, Eglin AFB, Florida. He was in on the ground floor of building the new unit and integrating its many diverse functions as the Group Vice Commander, before he took over as Commander in March 1977.

"Flying drones is not really new," says Colonel Witzel. "SAC flew reconnaissance drones in Southeast Asia for several years. The nature of their mission required reduced publicity on drone operations as such, but the idea of reducing manned aircraft exposure to hostile environments is proven. Drones, nevertheless, are very unique, and we're excited about the role of drones and how to apply this highly versatile, tactical vehicle."

Enthusiasm, determination, and dedication all pour forth when Jim Witzel talks about his mission and his command. He went on to tell how the unique operational capabilities of Remotely Piloted Vehicles were established.

They require no human support systems, so they are much less expensive than manned aircraft and they can accept a much higher "G" load. Of course, the lack of human exposure in a hostile environment is an obvious drone attribute.

Besides the drones themselves, Colonel Witzel's 432 TDG maintains and flys DC-130A and DC-130E "Hercules," plus CH-3E helicopters specially modified to make mid-air retrievals for the drones. The DC-130s serve as launch platforms for the RPVs and provide aircrew stations for the launch and control of the drones in flight. "Incidentally," interjected Colonel Witzel, "the Launch Control Officers and Remote Control Officers are navigator and EW positions besides the aircraft navigator."

The drones may be flown manually through remote control—or they can be flown "hands-off" by a programmed computer carried aboard the drone. After its flight is complete, the drone is "recovered" in a multiple-parachute system which is snagged by the catch helicopter. It is then winched into a stowed position below the CH-3E and flown to a docking pad where it is lowered gently to earth.

While operating these varied air vehicles is demanding, maintaining them is even more so. Colonel Witzel admits that the uniqueness of his Group's mission and equipment sometimes causes headaches. "Many of the sub-systems and special equipment on our aircraft were made in small batches," said the Colonel. "And, we're often perplexed in our attempts to locate a part that hasn't been manufactured in like kind for some time. But all that adds to the challenge of the job, and we've never yet encountered a problem we couldn't whip."

One of TAC's first units to arrange its maintenance efforts according to POMO (Production Oriented Maintenance Organization), the 432d has both a Drone Generation Squadron and an Aircraft Generation Squadron to keep the respective equipment maintained and flying. On the operations side, there are two flying squadrons. The 11th Tactical Drone Squadron principally flies "A" model 130s, plus a contingent of CH-3Es, and the TEWS drones. The 22 TDS flies DC-130E and CH-3E aircraft and currently provides the Air Force with its only operational reconnaissance drone system. But, enough about the unit—more about the man.

Jim Witzel was born in Seattle, Washington, 11 April 1936, and still holds a great affinity for the Northwest. He finished high school at Drain, Oregon, in 1954, and went on to Valley Junior College in Van Nuys, California. In June 1956, he entered the Air Force and received a commission through the Aviation Cadet Program in August 1957. He later earned a Bachelor of Science degree from Troy State University, Troy, Alabama. His military education includes Squadron Officer School in residence and the Industrial College of the Armed Forces.

After navigator training at Harlingen AFB, Texas and advanced Navigator-Bombardier training at Mather AFB, California, Colonel Witzel served with the Strategic Air Command as a B-47 navigator-bombardier from 1958 into 1966. Following that, he saw action in Southeast Asia as a C-130B navigator with the 463d Troop Carrier Wing and advanced to a position as Wing Navigator.

After his SEA tour, Colonel Witzel took his family to Europe for five years. He flew as an RF-4C WSO with the 38th Tactical Reconnaissance Squadron for two and one-half years before becoming the 26th Tactical Reconnaissance Wing Operations and Training Officer. He later became the 26 TRW Operations Plans Officer and had a final assignment with USAFE as Chief of Radar Systems Division for Headquarters, 17th Air Force, Ramstein AB, Germany.

Colonel Witzel's military decorations include the Meritorious Service Medal, Air Medal with two OLCs, Armed Forces Expeditionary Medal, Vietnam Service Medal, and Republic of Vietnam Gallantry Cross.

Jim's delightfully effervescent wife is the former Judith N. Brown of Reedsport, Oregon. They have two daughters, Kelly Sue and Kassandra Rene.

Colonel Witzel acknowledges that being the Commander of the Tactical Drone Group is the high point of his career. While admittedly proud of his own attainment, he is also pleased that his example helps open new opportunities for navigators within the Air Force. (Lt Col Calvin R. Johnson, a navigator, commands the 22 TDS, and Lt Col James J. Fitzgibbon, an EW, commands the 432 DGS, both under Colonel Witzel.)

"We have something like 30,000 pilots and 15,000 navigators in the Air Force today," remarked the Colonel. "We have not used good navigators with valuable experience because public law simply prevented the qualified navigator from having a flying command assignment. The law has been changed, I hope that navigators will use this trend and take my assignment as proof that the Air Force plans to use qualified people in places where they can be most effective."

From The Editor

Submitting an article:

All too often I hear the comment, "I would like to write an article for *THE NAVIGATOR* but my English usage and spelling leave something to be desired." If this is your hang-up, put your mind at ease. *THE NAVIGATOR* will take care of those smothered verbs, passive voice, and misspelled words. Anyone with a short cut to describe, an experience to relate, or any comment to make can and should submit a manuscript to *THE NAVIGATOR*.

The basic criterion for manuscript publication is that the article must be navigation related or of interest to navigators. This includes articles such as the leadership article in this issue, or "MBO" found in the Spring 1977 issue. Certain specific restrictions should be noted, however. Articles must *not* be: (1) classified, (2) in conflict with DOD or USAF policies, (3) a verbatim restatement of AF regulations, manuals, technical orders, etc, or (4) a reprint of material which recently has been accessible to Air Force navigators.

Manuscripts should be double-spaced and include a suggested title and the author's name, grade, organizational address and AUTOVON number. A short biographical sketch (six to seven lines) and a 5x7 black and white glossy photograph of the author in class A uniform should be included with each article.

A picture or diagram is worth a thousand words—an old cliché, certainly, but often so very true. Illustrative material is often the key to putting the idea across. The author should carefully consider whether or not the manuscript would be improved by the addition of photography, diagrams, charts, etc. Whenever possible, the photos should be 5x7 glossy black and white prints. Don't feel that you must send "camera-ready" graphics, however. A very rough sketch or a described idea can usually be turned into an outstanding piece of artwork by the art editor.

Manuscripts submitted should include a letter from the appropriate Office of Information (normally at your Wing) which indicates a security and policy review and clearance for publication in accordance with pertinent AF and command directives.

Submit manuscripts to:

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323 FTW/DOTN
Mather AFB, CA 95655

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THE NAVIGATOR

AFRP 50-3, Volume XXIV, Number 3, Winter 1977

UNITED STATES AIR FORCE

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Published triannually by Air Training Command with funds approved by Headquarters, United States Air Force. Distributed, in accordance with Air Force Regulation 7-1, through the Air Force Publication Distribution Center on the basis of one copy for each two navigators.

Manuscript contributions are welcomed, as are comments and criticisms. Contact the Editor at the address below or at AUTOVON 828-2138 before extracting from or reprinting material. Opinions expressed by individual contributors do not necessarily reflect the official viewpoint of the Department of the Air Force.

Address manuscripts to Editor, THE NAVIGATOR Magazine, 323 FTW/DOTN, Bldg. 3860, Mather AFB CA 95655. Address subscriptions to Superintendent of Documents, GPO, Washington DC 20402: yearly $3.00 domestic, $3.75 foreign; single copy $1.00. Air Force Recurring Periodical 50-3.

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NAVSTAR, a revolutionary new navigation aid, is the subject of our cover story for this issue. Discover what it is, how it works, and how to use it, beginning on page 5. THE LONE EAGLE pays tribute to Charles Lindbergh's solo Atlantic flight. Also included are two articles on electronic calculators—one discusses the usefulness of the calculator in navigation while the other presents formulas for solving the myriad of problems associated with navigation.

NAVSTAR

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INTRODUCTION

Accurate position determination has been a prerequisite for successful navigation ever since man began to travel. As man ventured farther away from land and his vehicle speed increased, his basic navigation requirements became more stringent. Today man must cope with increased air traffic and the requirement to navigate accurately in all types of weather, in hostile conditions, and on a global basis. Navigation systems or aids to assist man's quest for travel, have covered the entire systems spectrum from basic celestial to low frequency (Omega) transmitters.

A new navigation system is now being tested as a navigation aid. This new system will employ satellites in orbit around the earth, transmitting continuous navigational information from an orbit of about 20,185 km. Called the NAVSTAR Global Positioning System (GPS), this modern navigation aid will produce three dimensional receiver positions accurate to 10 meters on a continuous, real-time basis for many types of users. In addition, GPS will continuously transmit a signal from which time information, accurate to within a fraction of a microsecond, can be derived. This article will introduce the reader to the basic GPS concepts, theory of operation, and application in the world of navigation.

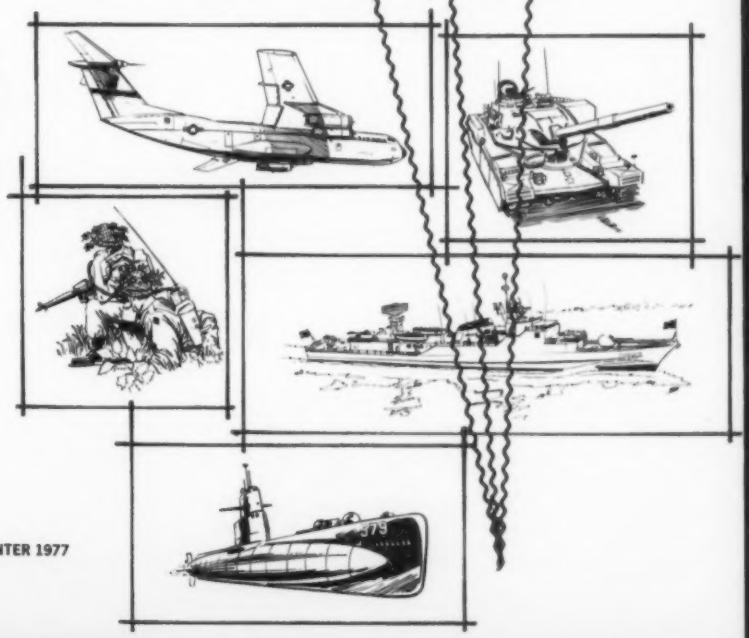
THEORY

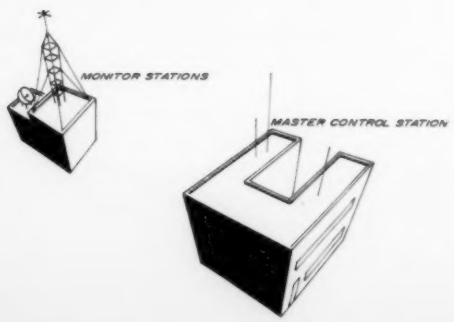
The use of satellites as navigation aids was developed in the early sixties to support the Polaris submarine missile system. This system, called TRANSIT and operated by the Navy, is still in use today. Receiver position is determined by measuring the Doppler shift from the satellite's transmitted signal. Real-time position determination and navigation by fast-moving aircraft are not possible due to the long viewing time required to take Doppler measurements. In addition, the limited number of satellites in the system does not provide continuous worldwide coverage.

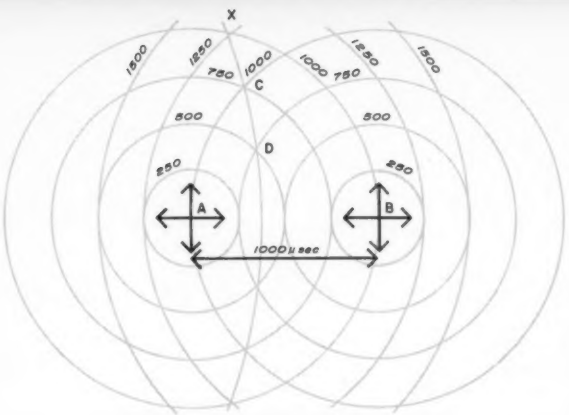
The NAVSTAR GPS now being developed by the Department of Defense will provide continuous, real-time navigation data. This data will be accurate to 10 meters and can be received by all types of users, fast or slow moving, on the earth, in the air, and in near earth space.

One immediately wonders why a navigation system with such outstanding characteristics has not been developed previously. If man has been successfully orbiting satellites for two decades, what developments in aerospace engineering have improved the state of the art to make the GPS possible. The GPS concept has become feasible due to recent developments in high-speed digital processing, improvements in satellite orbit prediction, and most importantly, improvements in the state of the art of space-borne clocks.

GPS operational theory can best be understood by relating it to passive TACAN Distance Measuring Equipment (DME). TACAN DME theory states that a sphere of constant range (radius) from a TACAN DME station is described







Generation of a Hyperbolic Lattice

by the product of the speed of light and the time interval (Δt) for transmission of a DME interrogation from an aircraft to the ground station and return to the aircraft divided by two. This would be expressed as:

$$R = \frac{C\Delta t}{2}$$

where C = speed of light

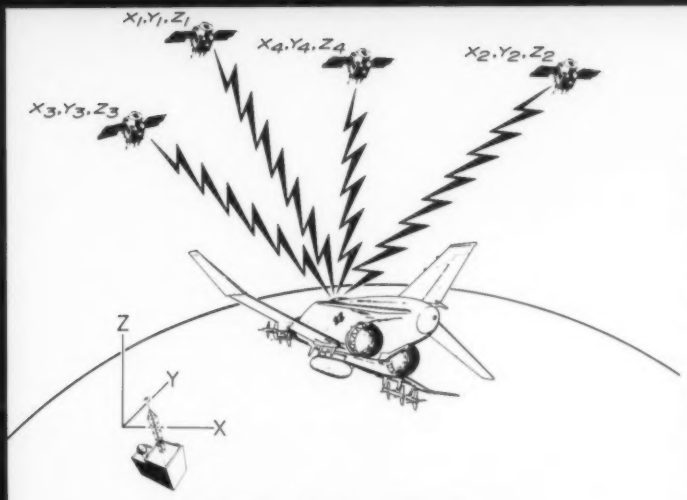
Δt = time interval from signal transmission to signal reception

TACAN DME is an active system in that a signal must be initially transmitted from the aircraft. Range from a satellite is determined by measuring the time interval (Δt) from satellite transmission to user or receiver reception and multiplying this interval by the speed of light. In order to calculate the range, the receiver must know the time of signal transmission from the satellite and the time of his signal reception. Due to the characteristics of the digital signal, the time of signal transmission is inherent in the transmitted signal from the satellite. This time is highly accurate and stable because all satellites contain space-borne atomic clocks.

If the receiver possesses a stable clock synchronized with the satellite clock (this is not the case as will be explained later), he can subtract the time the satellite transmitted the signal from the time that his clock indicates that it received the signal. This time interval, multiplied by the speed of light, will produce a sphere of constant radius whose center is at the satellite on which the receiver is located. (Time delays due to the atmosphere and to the equipment must also be considered, but they are not essential to an understanding of basic GPS theory.) With two satellites in view, the user can calculate a line-of-position from the intersection of two spheres. A third satellite provides an additional sphere-of-position whose intersection with the other two will define a three dimensional navigation fix. The accuracy of the navigation fix would be dependent on: (a) the accuracy of the measurement process (how accurately is the digital signal processed), (b) the accuracy of the satellite positions, and (c) the accuracy and stability of the satellites' clocks and the receiver clock. The user equipment is expected to be able to track the satellite's signal to within 3 nanoseconds (3×10^{-9}). This is equivalent to a one meter error in position.

If navigational accuracy on the order of 10 meters is desired, we must be able to establish satellite position at a particular time to within at least 10 meters. This is not a trivial problem. Since the satellite is moving and is subject to complex gravity attractions and solar wind, measuring and predicting its position within 10 meters as a function of time is quite difficult. The ability to accurately determine satellite position at a particular time is one continuing development which has made GPS possible. Highly accurate satellite range and range rate measurements, combined with vastly improving estimation theory techniques such as Kalman filtering, have contributed to this success. Kalman filters use a sophisticated statistical weighting process of previous range and range rate measurements to predict what the satellite position will be at a particular time in the future. These Kalman filter techniques are accomplished by high speed digital computers to give the ground based satellite system monitor the ability to accurately predict individual satellite positions at all times. This information on future satellite positions, as well as time information, is uploaded to the satellites on a daily basis. The satellites will continuously transmit this information to all users.

The most important factor to be considered relates to the accuracy of time measurement. If the receiver expects to calculate an accurate surface or sphere of position by measuring the time difference between signal transmission and reception, all transmitters and receivers must be extremely well time synchronized. This synchronization will insure that all satellite signals are transmitted simultaneously. In order to establish LOPs with 10 meter accuracy, we must be able to measure a time difference on the order of a few nanoseconds (10^{-9}). Recently developed atomic space-borne clocks have frequency stabilities on the order of 10^{-13} seconds per second for a period of about one day. Given such stabilities, a time hack once a day, or about 10^5 seconds after synchronization, will be



Pseudo-Ranging to Four Satellites

accurate to about 10^{-8} seconds (10^{-13} sec/sec x 10^{5} sec = 10^{-8} sec). Very expensive cesium atomic clocks will be installed in the navigation satellites to achieve this level of accuracy.

To achieve 10 meter positioning accuracy would also require that all users have an atomic clock comparable to the satellite clocks. This approach, however, would significantly increase receiver cost. The requirement for an expensive user clock can be eliminated by insuring that four satellites are visible to the user. By using four satellites, the user will be able to synchronize his clock to the satellite clocks each time he takes a fix. Because user time between fixes, as well as time synchronizations, may be on the order of one second, his clock must only have a short term frequency stability of about 10^{-8} sec/sec to produce 10^{-8} seconds timing accuracy over the one second fix interval (10^{-8} sec/sec x 10^{0} sec = 10^{-8} sec). Quartz crystal clocks, which are considerably less expensive than atomic clocks, are currently available and can easily provide such accuracy.

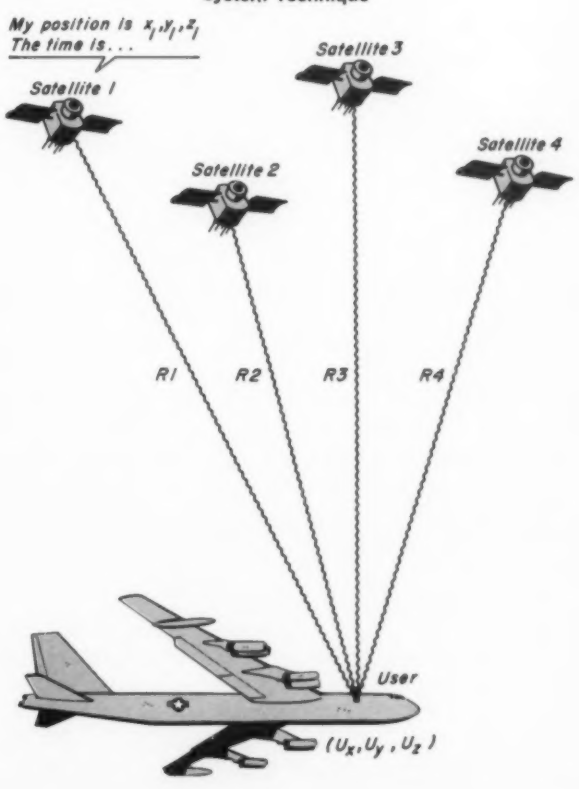
Because user receiver cost is an important criterion, the standard GPS navigation technique will require four satellites to solve the navigation problem. Solving this problem requires the solution of a system of four equations and four unknowns. These unknowns are the three coordinates of the user and his clock bias. These coordinates could be latitude, longitude, and altitude. An example of these equations is shown, the four unknowns being the user coordinates U_X, U_Y, and U_Z, and the clock bias, C_B with units of meters.

$$(X_1 - U_X)^2+(Y_1-U_Y)^2+(Z_1-U_2)^2 = (R_1 - C_B)^2 \qquad R_1 = C\,(\Delta T_1)$$
$$(X_2 - U_X)^2+(Y_2-U_Y)^2+(Z_2-U_2)^2 = (R_2 - C_B)^2 \qquad R_2 = C\,(\Delta T_2)$$
$$(X_3 - U_X)^2+(Y_3-U_Y)^2+(Z_3-U_2)^2 = (R_3 - C_B)^2 \qquad R_3 = C\,(\Delta T_3)$$
$$(X_4 - U_X)^2+(Y_4-U_Y)^2+(Z_4-U_2)^2 = (R_4 - C_B)^2 \qquad R_4 = C\,(\Delta T_4)$$

In this problem where the user does not have a highly accurate, stable clock, the solution of these four equations results in a range difference technique, which is similar to a hyperbolic system such as Loran. When these equations are solved simultaneously, it is only necessary to measure the time interval between the transmission of two satellite signals.

It is not within the scope of this article to produce this result mathematically; however, the problem solution is similar to a hyperbolic Loran system. With Loran, the receiver measures the time difference between two signal reception times to calculate a hyperboloid of position. Because all four satellite signals are received at the same time, only their time of transmission (which is a function of their range) will differ. By inspecting the four satellites or hyperbolic solution, but using only two satellites to do so, we can best show by example the basic solution. This hyperbolic solution requires the receiver to measure the time difference between two satellite transmission times rather than two reception times. A brief inspection of two of the equations will show how this hyperbolic solution develops, eliminating the requirement for an atomic clock in the receiver.

System Technique



First define:

t_{Tx1} = time of satellite 1 signal transmission
t_{Rx1} = time of satellite 1 signal reception
$\Delta t_1 = (t_{Rx1} - t_{Tx1})$, satellite 1
$\Delta t_2 = (t_{Rx2} - t_{Tx2})$, satellite 2
C = speed of light
CB = C (Et), clock bias in units of meters
Et = clock error in time
X_1, Y_1, Z_1 = coordinates of satellite 1
U_x, U_y, U_z = coordinates of user

Now, rewrite equations 1 and 2 as:

$$\sqrt{(x_1 - u_x)^2 + (y_1 - u_y)^2 + (z_1 - u_z)^2} = C\,(t_{Rx1} - t_{Tx1}) - C_B$$

$$\sqrt{(x_2 - u_x)^2 + (y_2 - u_y)^2 + (z_2 - u_z)^2} = C\,(t_{Rx2} - t_{Tx2}) - C_B$$

Subtract equation 2 from equation 1:

$$\sqrt{(x_1-u_x)^2+(y_1-u_y)^2+(z_1-u_z)^2} - \sqrt{(x_2-u_x)^2+(y_2-u_y)^2+(z_2-u_z)^2} =$$

$$C\,(t_{Rx1} - t_{Tx1} - t_{Rx2} + t_{Tx2}) - C_B + C_B$$

Because all signals are received simultaneously, $t_{Rx1} = t_{Rx2}$ and the right side of this equation reduces to:

$$= C\,(t_{Tx2} - t_{Tx1}).$$

By including the other two equations in the system, and differencing them, the data processor can eventually solve for U_x, U_y, U_z, and C_B.

This solution then becomes similar to a hyperbolic system. This is because range differencing, or the time difference between two satellite transmission times, $(t_{Tx2} - t_{Tx1})$ is used to calculate a surface of position, rather than a time interval between one satellite signal transmission and reception to calculate a direct range.

Therefore, four satellites will yield three range difference measurements allowing the user to position himself at the intersection of three hyperbolic surfaces. The intersection of these surfaces defines his navigational position. The hyperbolic analysis describes the performance characteristics of the GPS using four satellites in order to determine three-dimensional position without a highly accurate expensive user clock.

TESTING AND SYSTEM DEVELOPMENT

GPS testing has not yet been conducted using satellites. A test range at Yuma Testing Grounds, Arizona, has been fabricated for testing proposed satellite accuracies and dynamic receiver capabilities. This test range uses ground stations to simulate satellites. A testing aircraft flies over the test range and receives signals from the ground stations to calculate its position. This test range is slated to begin operation in summer 1977 and will be used in conjunction with the first constellation of satellites. Previous tests at Holloman AFB, New Mexico, have tracked aircraft position with cine theodolites and compared them to GPS receiver position. Results from these test runs have never shown the two position comparisons to exceed 50 feet in any of the three axes.

The first satellite was launched in June 1977 with a second planned for launch in fall 1977. After initial testing with the satellites, additional satellites will be launched in successive two-month increments to ultimately fill a constellation of six satellites. This constellation will provide sufficient satellite coverage to acquire position fixing data over North America on a limited time basis. The operational system eventually will deploy three planes of satellites in circular orbits of about 20,185 km at an inclination of 63°. Each plane will contain eight satellites, bringing the system total to 24 when fully operational. Full system deployment is now planned for completion around 1984. This deployment insures that at least six satellites are continuously in view from any point on earth. The minimum number of satellites in view will vary from six to eleven, depending on the latitude of the observer. With a minimum of four satellites required to obtain a position, there is a redundancy of at least two to seven satellites in the system at all times. Individual GPS satellites will weigh about 1000 lbs. and broadcast navigation signals on 1227.6 and 1575.42 MHZ.

The entire satellite system will be monitored and updated from ground control stations. This will facilitate usage and lower receiver cost. The primary purpose of the ground control segment is to track the satellites, predict their future positions, and predict satellite clock errors. Satellite tracking stations will be distributed around the world to measure satellite orbital

parameters and transmit the information to the master control station at Vandenberg AFB, California in Phases I and II and central CONUS in Phase III. The computing facility for the entire satellite system will be located at the master control station. Here the Kalman filtering or statistical estimation techniques are programmed into the computer to calculate satellite position and clock errors. This information is then transmitted to each satellite to constantly upload its computer memory with position errors and clock errors. Each satellite will then continuously transmit this information to all users on the two L-band carrier frequencies. With this information, each user can calculate his present position and the correct time as previously explained.

USERS AND RECEIVERS

Any type of receiver, ranging from a foot soldier to a highly maneuverable fighter aircraft, is a potential user. In general, users or receiver types are classified by the dynamics of the vehicle and the vehicle operational environment. A fast moving, highly maneuverable fighter in a potentially high jamming environment would require a much more sophisticated receiver than would a slow moving naval surface vessel. Receiver cost can be kept much lower if an accurate clock is not required. This can easily be accomplished by simply listening to four satellites. In general, receiver cost will depend on the amount of sophistication desired. Current estimates project the most sophisticated receivers cost about $30,000 while the least sophisticated costs about $10,000. These prices are quite attractive when compared to existing navigation systems which have fewer capabilities. Currently, a TACAN unit costs about $5,000, while inertial navigation systems cost about $80,000 to $100,000.

ADVANTAGES

The Global Positioning System has many advantageous characteristics. The most significant of these are:

a. Accurate (to 10 meters) three dimensional indication of aircraft position as well as highly accurate time information.

b. A worldwide common grid available to all users.

c. Passive all weather operation.

d. Real-time continuous information available to all users.

e. Unsaturable usage or no restrictions to the number of users at any one time.

f. Low life cycle cost to the user and the system.

g. The entire system possesses a graceful degradation due to the redundancy in the number of satellites in view and the number required to obtain a fix position. Moving satellites in 20,185 km orbits are significantly more difficult to destroy than stationary ground based Omega or Loran stations.

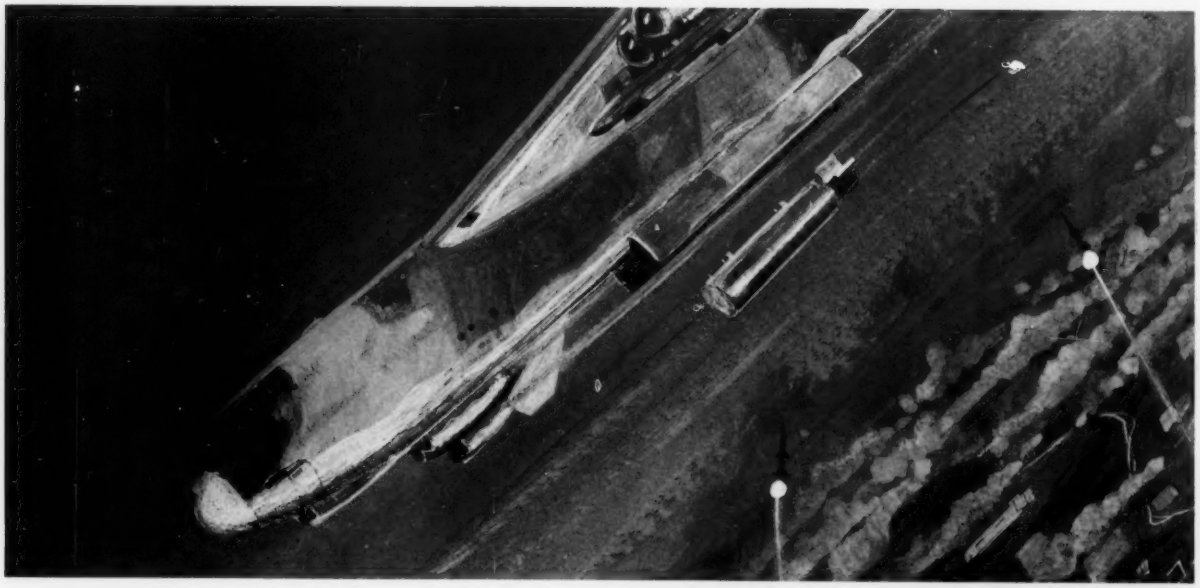
CONCLUSION: WHAT ABOUT OUR JOB?

What does the advent of GPS mean to the navigator and his role in the Air Force flying mission? This may be a significant consideration, realizing that soon we will have a navigation system that is simple to operate and capable of three dimensional accuracies within 10 meters on a real-time, continuous, worldwide basis. The impact is difficult to ascertain, but we must always consider the necessity for a reliable backup system. This is especially true on a complex navigation mission flown through a hostile environment. Other systems such as Omega or inertial may be integrated with the satellite system. An inertial navigation system periodically updated by GPS inputs might prove to be the best overall integrated navigation system. Regardless of the eventual system, however, man still must be available in most situations to make the logical navigational decisions necessary to successfully complete the mission.

Maj Garcia is a 1965 graduate of the University of South Florida. After missile duty at Ellsworth AFB, he graduated from UNT in 1968. An exchange tour with the RAF College of Air Warfare was preceded by a SEA assignment in EC-47s and C-141 duty in MAC. Maj Garcia recently left an assignment as chief of the Advanced Aviation Branch at the AF Academy to attend the AFIT MS resident program in laser-optics. He is a previous contributor to THE NAVIGATOR.

Capt Daniels graduated from the US Naval Academy in 1967 and from UNT in 1968. A SEA tour in EC-121Rs was followed by assignment to Langley AFB in the C-130E. Captain Daniels received an MS in Aerospace Engineering through AFIT at the University of Texas. Presently assigned to the Aviation Science Division, USAF Academy, he is an assistant professor and course director of Avionics Concepts and Systems Development as well as Independent Research/Study.

NEW TRICK *for an* OLD BUFF



Captain Robert A. FRYE
449 FTS
Mather AFB, CA

Precision radar bombing is the principle means the strategic bomber uses to strike a target. To accommodate the wide variety of missions and targets assigned to the B-52 force, an offset aiming point (OAP) capability is incorporated in the bombing-navigation system (BNS). This enables the radar navigator to bomb "no show" targets—ones which are not radar reflective or ones in a cluttered radar environment.

Until recently, the BNS was limited to two OAPs per synchronous target. These offset values were set by the navigator prior to each release. Special consideration had to be taken in selecting offsets for multiple synchronous releases to allow the navigator time to set the next offset values. Some B-52s were modified with dual offset panels which gave the potential of four offsets per target. This option required careful coordination between the radar navigator and the navigator to fully utilize its capabilities. The dual offset panels still required the navigator to manually set any offset values required.

The automated offset unit (AOU) is being added to the B-52 "G" and "H". It is designed to overcome the drawbacks of the analog offset system, plus provide additional capabilities to the ASQ-38 bombing navigation system. The AOU is a single, self-contained unit that replaces the present offset panels. The AOU computer stores and processes the coordinates of the mission data points. It processes the appropriate coordinates to position the tracking and bombing loops of the BNS. At the top of the AOU is a card reader used to insert preprogrammed mission data from computer punch cards. Below the card reader is the display window. Light emitting diodes (LEDs) provide an easily readable display of mission data—elevation, latitude, and longitude of the point. Next are thumbwheels for manually inserting or correcting mission data. The lower third of the AOU consists of the selector switches used to execute the various computer routines.

Power is applied to the AOU during normal BNS power application. Normally, the software program is preloaded by maintenance. However, the aircrew can load the software routine through the card reader if not previously inserted. The AOU is now ready to accept and process the mission data. Once the mission data has been inserted and verified the AOU is ready for use. The computer has the capability to test itself and the data load through special codes. For example, the AOU can determine if any target cards for the mission have not been loaded. The AOU even reminds an absentminded radar navigator to go to bomb function with the BNS.

Each target number can have up to four discrete OAPs associated with it. However, the same coordinates can have more than one target number. One target could therefore have more than four offset values assigned to it. Four offsets are normally all the radar navigator needs to attack a target.

The proof of the AOU is in its use. Regardless of the equipment, all bomb runs begin with a basic time and heading to the target. Once in range the BNS can automatically position the crosshairs on the target. Since there can be four offsets per target, the acquisition offset (OAP #1) can be a readily identifiable point near the IP. This allows the bomber aircrew to start the bomb run prior to reaching the IP. Checklist coordination items can be completed, and at the IP the pilots will have an accurate heading presented on the FCI (flight command indicator). The radar navigator can use the additional offsets to further refine the BNS for release. This becomes especially useful at TA (terrain avoidance) altitudes which limit the forward range of the radar. The radar navigator uses the additional offsets to "step" his way down the bomb run. He can synchronize on OAP #1 until OAP #2 becomes visible, on OAP #2 until OAP #3 becomes visible, etc. Since all the mission data is stored in the AOU memory, the navigator is freed from changing offsets. He can now more effectively assist the radar nav in target/OAP acquisition and identification. The navigator also has more time to monitor flight instruments, the BNS, and the Short Range Attack Missile (SRAM). This allows the radar navigator to devote more attention to aiming.

The AOU processes all offset information electronically. Therefore, rapid multiple synchronous releases can be accomplished. Through the multiple target (MULTI-TGT) feature, after each release the AOU can automatically position itself on the next target to be attacked. The release offset for the first target becomes the acquisition OAP for the next target. Under certain target area combinations one radar return can serve as the release OAP for a series of targets. The radar crosshairs will track a single point throughout the bomb run while the AOU positions the BNS bombing loop on each successive target.

The AOU can be used in other ways. Since the target to OAP distance has been increased significantly the area available from which to select OAPs has been expanded. With the extra distance between OAPs, BNS heading error can be readily detected and corrected through the translate-and-rotate (ground heading check) method. With its large memory capacity the AOU can store enroute navigation points, with associated offsets, as well as target data. It provides a valuable aid for precision, radar-directed navigation, especially during TA flight. The AOU-generated offsets allow the navigator team to "step" their way along the track. The FCI can be used to steer the B-52 along course to "no show" turn points. The AOU offset values can also be used for SRAM checkpoint fixing (correcting the inertial position). Using offsets, it is possible to collate the SRAM update with an enroute navigation point. This enables the SRAM inertial computer to be corrected while steering the aircraft with the FCI. Offset values could allow the SRAM to be updated on precision fix points that normally could not be used due to SRAM computer range limitations.

The AOU is a significant addition to the B-52 offensive avionics. It simplifies the aircrew workload and provides additional capabilities not previously practicable. As more units are modified additional uses for the AOU will be found along with the refinement of its present capabilities. With the addition of the AOU the B-52 continues to maintain SAC's strategic capabilities into the future.

Commissioned through OTS in 1971, Capt Frye graduated from UNT in September 1972 and NBT in January 1973. TDYs to SEA for Arc Light operations interrupted regular nav B-52 duties. He was upgraded to radar navigator in March 1976. Capt Frye was transferred to the 449 FTS, Mather, in October 1977.

The Lone Eagle

Captain K. N. GIFFARD
323 FTW/DOTN
Mather AFB, CA

Charles Lindbergh was perhaps the most celebrated aviator of all times. His skill and triumphs have been praised by millions. However, his feat of navigating the Atlantic has been slighted as being the product of luck.

Was his successful navigation luck, or was it more of a calculated undertaking than is commonly admitted? Lindbergh rarely left any endeavor to chance. On a fall night in 1926, he first perceived the New York to Paris flight as a possible undertaking. Before trying to sell his idea, he methodically outlined the reasons why his single-engine, solo flight would be successful. Then he developed plans for securing financial backing for the flight.

In late February 1927, Lindbergh traveled to San Diego where he engaged Ryan Airlines to start constructing his airplane. He was totally involved in developing and constructing the airplane and spent many hours detailing the aircraft with the engineers and craftsmen.

Concurrent with the work on the "Spirit of St. Louis" was the planning for navigating the Atlantic. Few men had practical experience in long-range overwater navigation and data was limited. Lindbergh relied upon his Army Air Service navigation courses, which were minimal, and an innovative spirit to solve that navigation problem.

At first tempted to seek advice in navigation from officers stationed at the nearby naval base, Lindbergh decided to forgo any such contact. He feared losing the confidence of both his financial backers and the Ryan employees laboring overtime to complete his airplane. Besides, he was supposed to be the knowledgeable expert.

He found his flight charts at a ship's chandler in San Pedro. Amongst a scattering of charts were a gnomonic projection and two Mercator projections covering the entire route, and several others including variation and prevailing winds. With these, he plotted his route in the fish-scented, chief engineer's office.

A straight route was drawn on the gnomonic projection from New York to Paris. Lindbergh segmented his route into 100-mile increments and transferred those points to the Mercator chart. This was predicated on a 100 mile-per-hour flying speed. Every point was annotated with elapsed time and compass heading for the coming segment. Concerned with route accuracy, he used spherical mathematics to recompute each point transferred to the Mercator. Satisfied when the points coincided, he sought the solution to maintaining his airplane on that planned route.

Celestial navigation seemed the logical solution. Since the number of pilots who knew celestial navigation were few, Lindbergh felt he could query the naval officers about celestial techniques without jeopardizing his backer's confidence. The Navy answer was short and perhaps welcomed. He might shoot some sunlines but night celestial was impossible. No one could fly an airplane and shoot the stars with any degree of accuracy. Radio navigation was discounted due to the heavy weight of the radio equipment. Lindbergh also noted that the radio frequently failed when needed most.

That left dead reckoning as his means of navigation. He would use an hourly routine of assessing wind-drift, checking magnetic variation, and applying these to his precomputed compass heading for each 100-mile segment.

Lindbergh's non-stop flight from San Diego to St. Louis was a practical test of his night navigation skill. Although his record-setting flight from California lacked in navigation accuracy, he reasoned that an operational earth-inductance compass and the practical navigation experience gained would contribute substantially towards improved accuracy on the Paris flight. The earth-inductance compass, chosen for its accuracy and ease of use, was the state of the art in 1927. Enthusiastically endorsed after the flight, Lindbergh acknowledged years later that this compass was useless during the critical night portion of the flight.

A Creagh-Osborne type whiskey compass served as a backup system. During the period that the inductance compass failed, the whiskey

compass was oscillating up to 60 degrees, but hesitated at the proper heading between swings. With that transitory but accurate heading information, Lindbergh steered the aircraft using stars on the horizon as aiming points. Drift was measured visually, estimating the wind effect on the aircraft. He occasionally flew the "Spirit of St. Louis" to within several feet of the wave tops to get his estimates. Unused and left on the aft cabin wall was the drift sight. Lindbergh was too fatigued to utilize it inflight.

Aside from an early 90-mile deviation to overfly St. Johns, Newfoundland, Lindbergh flew the route as planned. His hourly heading changes were based on his analysis of drift, magnetic variation, planned compass heading, deviations made for weather, and compensation for his overfly of St. Johns.

The "Spirit of St. Louis" passed within three miles of its intended landfall in Ireland although arriving two hours early. A one-degree heading change from one of the two lost hours was the only deviation from the planned route.

No one could say that the flight was inadequately prepared. Its success attests to its adequacy of planning. By his nature, Charles Lindbergh approached any complicated matter in a deliberate and systematic manner, taking pains to insure success and leaving little to chance. Characterized by the press before the flight as a backwoods daredevil and called the "Flying Fool," he returned from his triumph called "The Lone Eagle," and "Lucky Lindy."

But was it luck? Charles Lindbergh resented the title, the song about "Lucky Lindy," and most of all, the implication regarding his preparation and execution of the flight. Lindbergh's response was, in essence, that good luck came to those who had made adequate preparation beforehand. One could not help but agree.

Capt Giffard is a 1969 AF Academy graduate. After UNT graduation in April 1970, he was assigned to F-4 duty at DaNang AB, RVN. The next four years were spent in stateside F-4Es, followed by assignment to Mather AFB. He is now the Director of the USAF Silver Wings Navigation Museum which will have a formal opening in January 1978. Capt Giffard is a previous contributor to THE NAVIGATOR.

A LEADERSHIP STYLE

Lieutenant Colonel William P. WILSON
HQ ATC/IGIX
Randolph AFB, TX

Among the rare qualities of Commanders the ability to lead is highly prized. Many definitions of leadership have been put forth during the various studies of command, struggles for power, and the ultimate design of management responsibilities. Such studies usually define leadership as the art of inducing subordinates to accomplish their assignments with enthusiasm and confidence. This requires a lot of work and personal concern on the part of the leader. To subordinates, the leader must provide guidance, limitations, direction, and inspiration. As a leader, you are part of the organization yet you're distinct from it. You function to help the organization attain its objectives with the maximum application of its capabilities. As the leader you try to take the proper place at the head of the organization, to facilitate subordinate progress, and inspire them to accomplish organizational goals. To specifically motivate subordinates, the leader obviously must know to what stimulus people will favorably respond. This requires a keen ability to know as much as possible about the people who work for you.

Some prefer to use the hard authoritarian approach to leadership or command situations, while others favor the more permissive strategies for both. At times leaders have had to resort to more of an authoritarian style than desired, but this is frequently the result of temporary pressure. How a leader performs under pressure or stress, however, is normally what subordinates remember.

A commonly heard phrase is "to lead by example." To lead by example in a stressful environment takes considerable energy. What happens when an exemplary leader takes over an organization and, in fact, "leads by example"? Milestones begin to be surpassed, standards exceeded, objectives improved, esprit de corps becomes evident, enthusiasm prevails, enormous workloads are accomplished and the leader continues to project the easy confidence of a commander ready to meet new and more complex challenges.

To lead by example and try to stimulate improved performance in subordinates requires the ability to empathize with those to whom you try to provide leadership. Try to assess their ambitions, biases, values, and objectives. In this regard, it is beneficial to keep reminding yourself that what motivates or satisfies you often may not motivate or satisfy your subordinates. A genuine concern for subordinates, peers, and supervisors, even though forced somewhat on occasion,will provide you with a well balanced, fully illustrative impression of these people. Learning their problems, weaknesses, strengths, and desires permits you to adjust your pressures, demands, limitations, suspenses, etc., on an individual basis and the results are considerably more rewarding for you and for them.

It is extremely difficult to find individuals who intentionally don't want to do well. Sometimes they don't know which way to proceed, or how far to go, but with a little stimulation or direction they do well. On some occasions, their desires may have been curtailed by previous bosses who called their efforts stupid or wasteful. In some extreme situations, people have been shunned by their boss because the boss didn't really understand them or what they were trying to accomplish.

A leader should be fair, and this requires unemotional objectivity which is sometimes the most demanding aspect of leadership. It is important to evaluate subordinates' efforts from a distance to determine the actual causes of results, and take intelligent steps to improve poor ones or to encourage good ones. Sometimes it takes strong will power to objectively analyze results or a problem before taking distinct corrective action.

Theoretically, as a leader, you should try to prepare subordinates for jobs of greater responsibility. Try to develop leadership characteristics in your subordinates. The basic reason for this is not to dominate their work but attempt to help them develop into leaders themselves. A measure of your effectiveness as a leader is reflected in their efforts to be leaders. You can certainly increase your effectiveness by helping them develop "take-charge" characteristics rather than forcing them to be only reactors to various circumstances.

Lt Col Wilson was a distinguished graduate from the Aviation Cadet program in 1961. He received his BS from Golden Gate University and MA from Webster College. He has served in MAC, AAC, MAAG, and ATC, while logging over 5,000 flying hours. In 1973-75, he was assigned as Assistant Deputy Commander for Navigator Training, Mather AFB. He is presently Chief, Programs and Analysis Branch, Inspection Directorate, HQ ATC.

THE WRITE-UP

Captain Mark R. THESSING
340 BMS
Blytheville AFB, AR

Probably one of the most overlooked and least emphasized parts of any training mission is its end when the time comes to complete the 781. This form is the most misused and abused of all the forms and paperwork crew members complete before, during, and after a mission. Even though this is one of the most important forms we'll complete for a mission, few of us take the time to complete it correctly. This is unfortunate when you stop to think of the effects that both good and bad write-ups have on you, a Wing's maintenance complex, and the Air Force as a whole.

Nothing can complicate a maintenance man's job faster than an unclear or vague write-up. Although this may seem unimportant at first, the problem takes on a whole new perspective when applied Air Force wide. One can only guess the untold number of wasted man-hours spent trying to fix a malfunctioning piece of equipment when a good, clear, and concise write-up would have resulted in an operational piece of equipment in half the time or less. The results are an enormous waste, in terms of Air Force money, man-hours, and training.

We, as crew members, can do much toward correcting this problem. There are many things we can do if we take the time to use the write-up for what it is—an extremely valuable maintenance tool. Let's take a look at a few! First, we should know as much as we can about all the aircraft systems relative to our own crew position. By doing so, we may be able to fix a malfunctioning system inflight, or, at least, be more knowledgeable and descriptive in our write-ups after we land. Also we lessen the possibility of incorrectly analyzing a malfunction or making an incorrect or misleading write-up at maintenance debriefing. Secondly, remember that maintenance personnel are not mind readers. They need and rely on all the information you can give. Never assume the maintenance man is going to figure out what you don't include in a write-up. Most of the time this just doesn't happen. Third, don't worry too much about grammar or spelling. You won't be graded on your write-up. Just concentrate on making the write-up clear. Don't try to spare any words either. Put things down just as they happened and take as much space as you need. Use more than one block if necessary to describe the problem. After all, that's what those blocks are for. Most maintenance personnel would rather have too much information (if that's possible) than too little. Also describe what you did attempting to correct the problem and if you had any luck. Fourth, don't try to hide a lack of knowledge by making a very short or incomplete write-up, or what's worse, no write-up at all. Put down what you remember and ask the maintenance specialist to assist you in completing the write-up. Feel free to ask questions at any time. By doing so, not only will maintenance get a much better write-up but you'll probably learn something too. Fifth, never be in a hurry when entering a write-up. A couple of extra minutes spent completing a good write-up could save a maintenance man a couple of hours of unnecessary work.

Some crew members have a hard time remembering all that happened concerning a problem or problems inflight. Some of them have even completely forgotten to enter a write-up concerning a small inflight problem. If this has happened to you, one possible answer might be to write down what you see as the problem develops, time permitting. If you can't do this, designate another crew member who isn't busy at the time to make short notes in the 781. This technique is often very helpful later during debriefing when you can go back and fill in some of the "holes" in the write-up. If this technique isn't agreeable to you then come up with one of your own. What's important here is that you have a plan and follow it.

Let's face it! Good maintenance, to a very large extent, begins with us, the crew members. We can only expect to get as much out of it as we are willing to put into it. Clearly, we will have to do our part before maintenance can do theirs. Let's help maintenance help us.

A 1971 graduate of the University of Central Arkansas, Capt Thessing entered the Air Force through OTS and then completed UNT and NBT. He is presently assigned to the 340th Bomb Squadron, Blytheville AFB, where he is serving as the Squadron Instructor Navigator. He will soon attend B-52 Radar Navigator Upgrade Training at Castle AFB.

My First Overwa

Captain Jerry E. ROSHTO
909 AREFS
Kadena AFB, Okinawa, Japan

Ever since I first enrolled in the school of navigation at Mather, I have been told of the most trying situation for a navigator—the overwater flight. I listened to these stories with great interest knowing that one day I would be faced with crossing a large body of water.

Following successful completion of navigation school, I was assigned to the 91st Air Refueling Squadron at McConnell AFB, Kansas. Aha, I thought. I'm safe. I could think of no place where crossing a large body of water would be more remote than the open plains of Kansas. Comforted by this thought, I reported to Castle for upgrading in the KC-135.

It took the 4017 CCTS instructors about an hour to dispel my feeling of safety. Almost immediately, they began to relate fear-laden experiences in the KC-135 aided only by the most antiquated equipment. This can't be right, I thought. I had better navigational equipment in the T-29! I thought the KC-135 was a modern aircraft!

When I reported to the 91 AREFS, I began to feel safe again. My first flights were uneventful. I hadn't seen a whole lot of water in any one place so I felt more at ease. Then the TDY roster came out and I found myself destined for Thailand. I had a terrible sinking feeling way down in the pit of my stomach, knowing without looking at any charts that Thailand had to be across some ocean. My worst fears were realized when the aircraft commander came up to me and said, "Are we ever lucky. We're going to fly the airplane over!" I smiled weakly and tried to look confident. All the while, terrible thoughts crept through the innermost channels of my brain: *"KC-135 Lost at Sea!"* or *"Deploying Aircraft Lands at Wrong Island."* What a heyday the reporters would have when we blasted into some tiny island that had just enough runway for a fuel-starved tanker to land but not enough for takeoff.

My bluff paid off. At the last minute, we were bumped from flying the airplane over by a "standboard" crew. Everybody was really "hacked off" about that act but me. I was secretly very happy.

The flight to Thailand was a hassle for us as passengers. I grumbled about how uncomfortable we were while the crew had lots of room and comfortable seats. I wouldn't have traded my cold, clammy corner for that nice warm seat the crew navigator had for all of the plotters and dividers at the "538 section!"

We arrived at U-Tapao Airfield in the wee hours of the morning on 3 December. The weather was warm and balmy, not at all like the winter weather we had left behind in Kansas. It really felt good to be off the airplane and on terra firma where I could stretch the cramps out of my poor legs.

We had our first flight three days later. It was a simple refueling mission. The lieutenant colonel who gave us our "over-the-shoulder" ride was really impressed and cleared us for the Force Logistics Sortie (FLS) without further adieu. I wasn't sure what FLS stood for, but it sounded important.

On the morning of 6 December, we were told that we would be taking the FLS flight out that afternoon. Wow! No mission planning, no emergency procedures test or anything, and we were going to fly. Still not too sure about what FLS stood for and with no idea as to where it went, I was really happy.

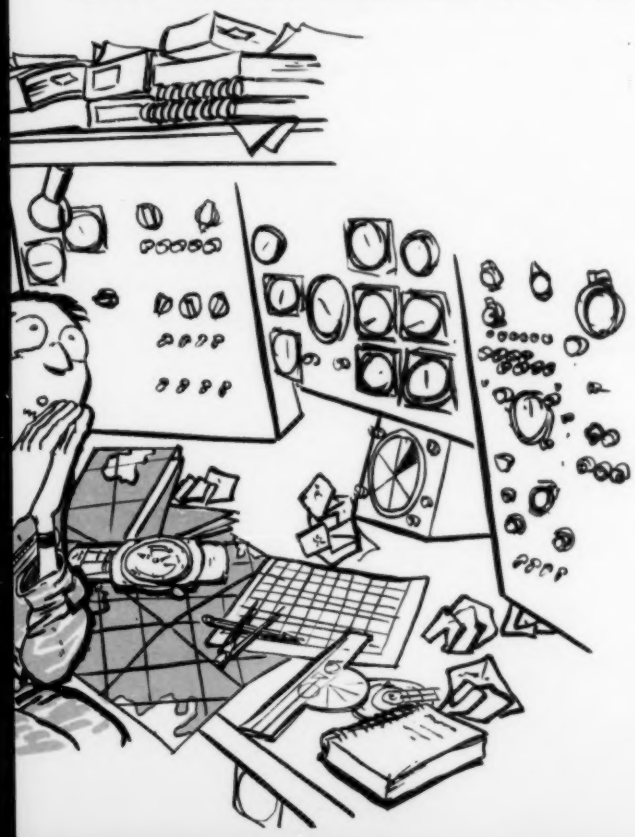
er Flight

We were at the Officers Club having lunch when I got up the nerve to ask someone just where the FLS flight went. The reply left me with no appetite for lunch. I kept muttering names like Guam and Kadena over and over to myself. I excused myself with some flimsy story about having to go check the mail and left.

I went back to the trailer and quickly dug out all the books I had brought with me to Thailand. If you have ever tried to cram for a test, you know how I felt pondering over the manuals containing what I needed so desperately to know. I studied pressure pattern techniques, pressure pattern by temperature, HF/DF steers, and even celestial techniques.

The bus picked us up about three hours prior to takeoff time. This enabled us to familiarize ourselves with the route of flight and attend all of the required briefings. We picked up the extra navigators (four of them) and one was even an instructor. I wasn't going to have to navigate after all. Was I ever relieved!

The first navigator flew a navigation leg to the Philippines and then the instructor sent him back to get me. I was going to fly the second leg. This isn't fair at all, I thought. He flew the overland/overwater portion and my leg will be entirely over water. There must be a SAC regulation that covers that kind of mistreatment of junior navigators.



I took my position sitting behind the copilot and tried with all of my strength to look confident. "Have you ever flown over water before?" the instructor asked. "S-Sure," I said. I hoped that he wouldn't ask if I had ever *navigated* over water before. I reached for some pre-comp forms and began to busy myself putting numbers in the blocks. My concentration was shattered when the instructor asked, "Don't you add the assumed longitude to the GHA to get the LHA in eastern longitudes?" There was a sudden roar of silence around the navigator's table. "Oh, yeah," I said. I repaired the error by balling up the pre-comp form and reaching for another. This time, I completed the form correctly. That was the only near panic of the whole trip for me.

We spent the next nine days on the beautiful island of Guam where it can rain two separate times in an hour and one can still get a sunburn.

We were in our room at the alert quarters on the 15th of December when the phone call came. "YOU are taking the FLS flight back to U-Tapao," the cheerful voice said. Everyone was excited—the voice, the pilots, and the boom operator. We were going back to our trailer at U-Tapao where the climate agreed with us.

The bus arrived outside the alert quarters at 1600 hours and the driver seemed in a hurry to go somewhere. We reached the aircraft safely despite everything the bus driver could do to the contrary. We unloaded our gear from the bus, and "bag-dragged" to the airplane. We then went through the myriad of checks that crews perform before a flight. The boom operator and I checked out the sextants until I had confidence in the two sextants aboard the aircraft.

We took off on the Andersen AFB famous runway with the decline in the middle and roared off the edge of the cliff. Complete with the instant 600 feet of altitude, we were on our way. As the gear was raised, I said to the boom operator, "Your next shot is in ten minutes!" He was somewhat startled as he was still doing his after-takeoff checklist.

As soon as he finished his checklist, I had the necessary numbers all ready for him. "The Zn of the body is 114.5." "Set," he replied. "The approximate height is 01-47." "I have the sun," he replied. "The shot starts in 45 seconds," I told him. "Roger." We completed the shots and I resolved the intercepts. The LOP fell about 3 miles from my DR which was right beside the TACAN fix I had taken. I was so proud.

Then I told him I wanted a heading shot. "Roger." I wrote down the N-1 reading and called the copilot for the J-4 reading, recording both in my log. "I want the heading in ten seconds, Boom." "Roger." "Five seconds." "Roger." "Boom, say heading now." "Roger, Nav, heading is 100." Bells began to ring. Something was not right they told me.

I thought for a few seconds. Our bus time was 1600 local. We took off about two hours later. The sun was nearly blinding us through the windshield and he gave me an easterly heading. Is he ever dumb! "Boom, come down here a second. What time of day is it?" I asked. "Evening," he replied. "Where does the sun go in the evening?" I asked. "To the west," he replied. "What is that shining through the windshield of the airplane?" I asked. "The sun," he replied. "Now, taking those tidbits of knowledge, why don't you get back up on that sextant stool and give me the correct heading?" I shouted. "Roger," he replied. "Nav, Boom, heading is still 100." Now, I don't claim to have calibrated eyeballs and I have had limited experience in dealing with compass deviation. But, how do you handle a compass and heading check that are 180 degrees apart? More bells ringing. There was something magical about that figure 180! I quickly shuffled my many papers around, found the HO 249 and checked the Zn. That would really be embarrassing to dump fuel and land because of a sextant. Then I noticed the small print at the top of the page, *"If the LHA is less than 180, subtract Z from 360 to get Zn."*

"Boom," I said, "set in 245.5 and tell me what kind of heading you have." "Roger, Nav, 245.5 set and heading is 280," said the boom operator, still quite confused from all the goings-on. "That's better," I said. The pilots had listened to all of this with acute interest. Thankfully, they had the tact or fear not to ask any questions.

Correcting this error with a minimum of rattling to my already shaky confidence helped me feel better. But it didn't do much for my boom operator who was now sitting on the sextant stool shaking his head. Undaunted, I pressed on. I quickly grabbed another precomp form and started to fill it out for the second shot. This time I was very meticulous in filling the squares. We were now out of TACAN range of Guam or "PGUA" as I came to know it. My celestial procedures would be very critical from this point on. Having finished the precomp, I decided the next important step was to restore my boom operator's very shaken confidence. I gave him the usual numbers and he relayed the heights back to me. After each shot, I was very careful to compliment him. I didn't want an upset boom operator on my hands. The LOP was terrific—it fell right through my DR. The heading had us pointed west so I was happy. The next couple of hours were very busy. I took celestial shots every thirty minutes despite the regulation that says you can wait up to 40 minutes between MPPs.

Everything went fine. The boom operator was confident once again, and I was extremely pleased when we set in the TACAN station at the Philippines. I told the pilot, "If my computations are correct, we should be driving in on or about the 093 degree radial." He quickly set in the frequency and channel and lo and behold, it locked on! We were indeed on the 093 radial. "You can rest now, Nav," he said, "I have a TACAN lock-on.....Good job." I was euphoric! My euphoric feeling lasted about 55 minutes, or the time it took us to over-fly the Philippines. Coasting out on the western side, I got a shocking interphone call. "Nav, Pilot, you can start navigating again."

I responded to the call by reaching for my precomp forms and began working frantically. I called the boom operator and told him to prepare for the next shot. "Roger" was all he said. He still hadn't become too talkative since the incident coasting out of Guam. I gave him all of the necessary figures, listening for the now familiar reply of "Set." Then my world fell apart! "The sun is below the horizon, Nav," said the Boom. "Oh, no," I thought, "It can't be! Isn't there a regulation that forbids the sun from descending below the horizon when a KC-135 is over the water?"

I extended the DR by 20 minutes and started frantically thumbing through the Air Almanac to locate a suitable celestial body to shoot. I precomped the stars—no luck. I precomped the moon and the LOP fell 136 miles from my DR. This can't be right I thought. I couldn't possibly be 136 miles off course in the space of thirty minutes from a known position. I threw the precomp form angrily to the floor.

The copilot finally turned on his interphone and said, "Nav, there is a bright star out of the right window that sure is big and bright. Why don't you shoot it?" I began to rack my brain to see if I could think of just what that bright star might be.

Nearing the extreme edge of human tolerance, I picked up the Air Almanac and stared blankly at the pages. I then noticed the names of those columns that appear on the right side of the page where I always go to get the GHA of the sun. The

names read Saturn, Jupiter...Could that possibly be a planet? I quickly began to precomp for Saturn, only to be interrupted by a call from the pilot. "What time do you estimate the ADIZ, Nav?" I pretended not to hear and pressed on with my work. The call persisted. "Hey," I shouted, "Do you want to know where you are or where you will be." I had ceased using the interphone. I didn't need it anymore. Besides, I was too busy to press the button. I listened wearily to the now silent interphone and precomped as I have never done before or since.

Finally, I was through. I quickly fed the numbers to the boom operator who was now ankle deep in thrown-away precomp forms. "Set," came the reply after each set of numbers was given him. At the end of the series, the boom operator replied, "I have the star, Nav."

The boom operator read the results of the shots and I figured the LOPs very carefully. Eight miles from the DR! We were saved! I lightly pressed the interphone switch and said, "Pilot, Nav, we will be at the ADIZ at 1146 Zulu." "Roger," said the pilot. He wasn't talking much either now!

I continued to shoot Saturn until we were able to pick up the coast on radar. Then my celestial ceased for the remainder of the flight. I had made it. "You can rest now, Nav," said the pilot.

We drove on in to the airfield and landed without my doing very much more. The only request from the pilots had been for a chock time so they could call for transportation. I tried to sound very professional on the reply.

After landing, we were really happy. "Hey, Nav," said the pilot, "You really did a good job." "Nothing to it," I replied. "I do have one question though," said the pilot. "What was all of that fuss about right after takeoff?" I looked out of the window of the crew bus and tried to look like I was reflecting.....

Capt Roshto graduated in 1970 from Northwestern State University, Louisiana. Joining the Air Force in December 1971, he attended OTS and then UNT. Following this, he was assigned as a crew navigator to the 91st Air Refueling Squadron, McConnell AFB. Capt Roshto was then assigned to the 384th Air Refueling Wing Standardization and Evaluation Section at McConnell. He is now assigned to the 909 Air Refueling Squadron at Kadena AB.

USAFA SIN

Major Henry A. BONDARUK, Jr.
Department of Aeronautics
USAF Academy, CO

When I reported for duty with the Department of Aeronautics at the Air Force Academy in October of 1974, little did I realize that my teaching duties would soon extend far from the labs and classrooms of the academic environment. Navigator rated personnel fill positions throughout the Academy organizational structure; we are on the Superintendent's and Commandant's staff, in the Directorate of Athletics, and on the Dean's faculty. Initially, as a rated faculty member, I began the normal routine of checking out in the T-29 at Peterson Field (now Peterson AFB) for my proficiency flying obligation. In the summer of 1975, a tremendous upheaval in the routine of teaching and proficiency flying hit the USAFA navs. The Academy acquired the use of the T-43A from ATC and the T-29 was headed for the boneyard. I found myself along with other selected Academy assigned navigators deeply involved in ground school and flight training for instructor duty with the Aviation Science Division (CWIN), then the Navigation Division.

In addition to the normal faculty member workload of teaching and directing courses, performing departmental additional duties, and participating in cadet oriented activities, the navigators may use their experience and skills in contributing to the mission of the Aviation Science Division under the Commandant of Cadets. As SINs (Support Instructor Navigators)

we are fully integrated into the CWIN staff and help conduct N3 trainer sessions, instruct on flight missions, and participate in summer orientation programs for new cadets. We also support the Deputy Commandant for Military Instruction by flying on MT (military training) 495 special training missions. As can be imagined, with about 30 SINs aiding 21 aviation science navs, the diverse backgrounds of Academy assigned navigators contribute greatly to the development of future Air Force officers. Besides teaching and flight instruction duties, we voluntarily serve as career advisors to graduating cadets.

The Aviation Science Division offers the cadets at the Academy a comprehensive curriculum ranging from studies in aviation fundamentals through applied studies in aviation and navigation theory to advanced concepts in avionics and astronomy. As instructor navs, we primarily support CWIN in the AV (Applied Aviation and Navigation Theory) 470 program. This course is an indoctrinational application of procedures and equipment operation ranging from dead reckoning through radio, radar, and celestial navigation. It is intended to develop an insight into the responsibilities of rated Air Force crew members through actual experience in a flight environment on local and cross-country missions. We are also used, on occasion, to instruct selected cadets in an advanced applied navigation course which serves as a lead-in to USAF Undergraduate Navigator Training.

A typical work week for a support nav assigned to the faculty might include assisting CWIN instructors in the N3 trainer on Monday for a two-hour block of instruction, then returning to the office to prepare the next day's lessons and performing departmental duties. Tuesday would be a day for teaching duties and Wednesday for an AV 470 flight mission. Flying days begin with a briefing at the Academy with the students at 0605 and a bus departure from Peterson AFB at 0700. A take-off time of 0900 puts the SIN back at the Academy at approximately 1300 from a "round robin" sortie or 1600 if a "Mather shuttle" is flown. The latter is used to rotate ATC aircraft and crews. The remainder of the day is used to prepare for the next day's teaching duties. Thursday would be a teaching day and hopefully time would be available to grade the previous day's missions. Friday involves completing grading and critiquing each student and preparing for the next teaching day. Once or twice each semester, support navs are also scheduled for a weekend cross-country either in support of AV 470 or MT 495. This involves a Friday afternoon briefing and departure with a Sunday afternoon return. In addition to cadet training flights, Instructor Validation Training (IVT) sorties are periodically scheduled to accomplish SIN upgrading, night proficiency requirements and annual flight checks. It is obvious that close coordination and cooperation are required to adapt each SIN's schedule to Aviation Science Division requirements. Through a great deal of effort, the system works to the benefit of everyone involved: The Aviation Science Division derives the use of additional instructors; the support navs fulfill flying obligations, retain currency, and are rewarded with the contributions they make to the development of future officers; and above all, the cadets are exposed to a diverse spectrum of experience on which to draw for personal career selection and development.

A faculty assignment to the Air Force Academy for a navigator involves living and working in two worlds; the world of academia and the world of flying. The workload may be awesome at times, but I am convinced you will never find a more rewarding working arrangement. It is truly satisfying to observe the development of a young man in the classroom and then share your experience and navigational skills with him in the air.

Maj Bondaruk is a 1965 graduate of the USAF Academy. After UNT and NBT, he was a B-52 navigator and radar navigator at Wright-Patterson AFB from 1967 to 1972 including two Arc Light tours. Major Bondaruk received an MS in Aerospace Engineering through AFIT at the University of Arizona. He then flew AC-130s at Ubon AB, Thailand, and served as a Department of Defense Air Operations Staff Officer, HQ 7AF/USSAG, Nakhon Phanom AB, Thailand.

NAV CALCULATORS

Major William E. BLUE
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The electronic calculator has become a hot item for navigators in recent years. The instruments have become smaller, carry more functions, and the price continues to drop. Two basic types are available. One is permanently programmed and the other has the program manually inserted each time the calculator is turned on. The permanent type has the advantage of long battery life and is built just to solve navigational problems. The manually programmed type is versatile and can do the regular navigational work. This includes DR, celestial LOPs, point-to-point measurements, pressure pattern, celestial motions, flight planning, orbit tracking exercises, and other unique algebraic problems. The unit must be left on after the program is inserted or reprogrammed after each turn on.

I purchased one of the permanently programmed types to perform independent research on the device. After it arrived the first order of business was to run the electromagnetic intolerance test. The test revealed a slight risk that the calculator might produce incorrect answers under high level electromagnetic conditions. This drawback is apparent in the answer and appears to be the only problem. However, in accordance with AFR 60-16, para 2-5, the calculator could be used on board aircraft without affecting flight safety and with little risk of degrading other equipment on board. I have tested the calculator on overwater flights in the Pacific and Atlantic on both day and night celestial navigation legs and found no interference in the operation of the calculator. My only problem has been operator error and the incorrect answer is apparent at first sight. The answer is either super accurate or so far out there is no way it could be correct.

The most advantageous feature of both types of calculators is solving for celestial line of position. By inserting the exact Local Hour Angle (LHA) of the Sun, planet or star, then the Declination (DEC) and last, the exact DR latitude, it produces the altitude and azimuth of the body. The height and azimuth are given in degrees, minutes, and tenths of minutes. To figure multiple bodies, such as the Sun, Moon, Venus, Jupiter, Saturn, and the stars, the same assumed position (DR position) is used. This eliminates one of the errors that has plagued navigators since the advent of celestial navigation.

After the observation is taken with the sextant the difference is plotted from a position next to the DR allowing for coriolis. Night celestial requires some computations during mission planning. My technique is to figure an estimated position and check for the best stars and cuts from Volume One of H.O. 249 and then extract the Sidereal Hour Angle (SHA) and the Declination (from the front cover of the Air Almanac) and list them on the precomputation form for use in flight. Precession and nutation is not a factor when using this method. With the manually programmed calculator a magnetic card can be set up for coriolis and motion corrections. One thing to remember when shooting the Moon—the calculator does not consider the special corrections for shooting the upper or lower limb and for the Parallax in Altitude (P in A). I know of one calculator user who has set up the calculator to figure pressure pattern by temperature differential readings. Most of the calculators will DR for you, but as of this time I have not found a way to DR using grid coordinates. The calculator figures convergence angle and induces an error in the grid DR.

A technique I use is to figure a Most Probable Position (MPP) each 10 minutes using one of three preselected stars and walk the DR into destination. I like to use 45 degree cuts off the nose or tail and shoot directly off the nose or tail in the opposite direction. This requires a lot of log work but results are well worth it. The sextant and personal correction should be used in this technique. Aircraft movement errors and incorrect star shots are readily apparent.

Maj Blue is a 1961 graduate of Aviation Cadets, Harlingen AFB. His first operational assignment was in KC-135s to Loring AFB. He was an instructor in the aircraft until 1972 when he was assigned to CCK AB, Taiwan in the C-130. In July 1973, Maj Blue returned to the KC-135 at Grand Forks AFB, and is presently Chief, DOTN at Grisson AFB. He is a previous contributor to THE NAVIGATOR.

NAV CALCULATOR FORMULAS

Captain James J. HAIRSTON
449 FTS
Mather AFB, CA

Recent technological advances have made the programmable hand-held computer readily available at a reasonable cost. If you don't desire the programmable type, a large number of other computers is available.

Air Force Systems Command has checked numerous computers and found them acceptable for use in flight. The list is available from Systems Command and was published in the February 1977 FLYING SAFETY magazine.

A new problem develops if you use one of these computers in flight since the old navigation formulas were dropped from AFM 51-40 long ago. I have obtained the following formulas from other sources:

Flight Planning

Given:
TC=True Course
TAS=True Air Speed
W/V=Wind

W=Wind Direction
V=Wind Velocity
DCA=Drift Correction Angle
GS=Groundspeed

$$DCA = SIN^{-1}\left[\frac{V \sin (TC-W-180)}{TAS}\right] \qquad GS = \frac{SIN\left[180-TC+(W+180)-DCA\right] \times TAS}{SIN\left[TC-(W+180)\right]}$$

NOTE: All angles should be in degrees and velocities in knots.

Celestial Computations:

LAT=Latitude of Assumed Position/DR
LONG=Longitude of Assumed Position/DR
TC=True Course
GS=Groundspeed

DEC=Declination of the Body from Air Almanac
LHA=Local Hour Angle
LHA=GHA+E/—W Long+SHA+corrections, etc.
Use Air Almanac for GHA/SHA, etc.

$$HC \text{ (Height Computed)} = SIN^{-1}\left[(SIN\ LAT)(SIN\ DEC) + (COS\ LHA)(COS\ DEC)(COS\ LAT)\right]$$

$$Z \text{ (Azimuth Angle)} = COS^{-1}\left[\frac{(SIN\ DEC) - (SIN\ LAT)(SIN\ HC)}{(COS\ HC)(COS\ LAT)}\right]$$

Zn=Z(N LAT and LHA>180°)
Zn=360—Z(N LAT and LHA<180°)
Zn=180—Z(S LAT and LHA>180°)
Zn=180+Z(S LAT and LHA<180°)

NOTE: Hc and Z will be displayed in degrees and decimal degrees. You must convert the decimal degrees to minutes.

$$1 \text{ minute motion} = \left[(15 \times COS\ LAT)\left\{COS(270-Zn)\right\}\right] - \left[COS(TC-ZN)(GS/60)\right]$$

$$\text{Coriolis} = \left[\text{COS}\left(90-(\text{TC}-\text{Zn})\right)\right] \times \left[.02625 \times \text{GS} \times \text{SIN LAT}\right]$$

$$\text{Rhumb Line} = \left[\left(.146 \times (\text{GS}/100)^2\right) \times (\text{SIN TC}) \times (\text{TAN LAT})\right]$$

In-Flight W/V Determination

Given:
TC=True Course
GS=Groundspeed
TAS=True Airspeed
TH=True Heading
DCA=TC—TH

$$V = GS^2 + TAS^2 - \left[2(GS)(TAS)(\text{COS DCA})\right]$$

$$W = TC - \text{SIN}^{-1}\left[\frac{(\text{TAS})\ \text{SIN}\ (\text{DCA})}{V}\right]$$

Pressure Pattern

$$\text{Zn} = \frac{K(D_2-D_1)}{\text{ETAS}} \qquad K = \frac{21.49}{\text{SIN (LAT)}} \qquad \text{ETAS} = \frac{\text{AIR DISTANCE}}{\text{TIME RUN}}$$

$$\text{BD (Bellamy Drift)} = \frac{(\text{Zn})(57.3)}{\text{GROUND DISTANCE}}$$

TAS/MACH (M)

$$M = \sqrt{5\left[\left(\frac{Po}{P}\left\{\left[1+.2\left(\frac{\text{CAS}}{661.5}\right)^2\right]^{3.5}-1\right\}+1\right)^{.286}+1\right]}$$

$$\text{where } \frac{Po}{P} = \frac{1}{\left[\frac{518.67-(3.566\times10^{-3}\times\text{Pressure Alt.})}{518.67}\right]^{5.2563}}$$

CAS=Calibrated Airspeed

$$\text{TAS} = 39 \times M \times \sqrt{(\text{IT}+273)\left[\text{CT}\left(\frac{1}{(1+(.2)(M)^2)}-1\right)+1\right]}$$

M=Mach
IT=Indicated Air Temperature
CT=Temperature Rise ("-1" for most aircraft)

Groundspeed and magnetic course from two tacan radials and DME readings or two radar range and bearings.

$$GS = \frac{\sqrt{D_1^2 + D_2^2 - 2A^2 - 2(\sqrt{D_1^2 - A^2})(\sqrt{D_2^2 - A^2})(\cos(R_1 - R_2))}}{T}$$

Where:
D_1=DME#1, D_2=DME #2
R_1=Radial #1, R_2=Radial #2
$A = \frac{HA - HT}{6{,}076}$

HA=Height above MSL
HT=Height or Elevation of the TACAN
T=Time run between radials and DMEs

$$MC \text{ (mag. course)} = R_2 + SIN^{-1}\left[\frac{(D_1)(SIN(R_1 - R_2))}{(GS)(T)}\right]$$

This computation is handy when flying from one radial and DME to another for computing the mag course and distance. The GS equation becomes distance if you do not divide by "T".

Capt Hairston, a graduate of Jacksonville University, obtained his master's degree in System Safety Engineering from the University of Southern California in 1977. He completed UNT at James Connally AFB and NBT at Mather. After serving on a B-52 crew at Altus AFB, he had C-130 assignments at Yokota AB and Dyess AFB. At present, he is an instructor in the 449th Flying Training Squadron, Mather AFB.

On a dark and stormy night

Captain Thomas J. ST PIERRE
11 AREFS
Altus AFB, OK

We were about an hour from coasting in when the weather started to deteriorate. It had been about 30 minutes since my last celestial fix and it appeared this might be the last one prior to coast in.

I had the other crew members scanning the sky for any available bodies to shoot. Finally the copilot said "I got one." The boom operator completed a couple of shots for an MPP while I tried to find out which star he was shooting. For help, I went to the sky diagrams located in the Air Almanac.

Like most navs, I'm sure you have faced the problem of having to identify bodies to shoot while under partially overcast or twilight conditions. The sky diagrams are one quick way to solve this problem.

There are four distinct advantages to using the sky diagrams rather than ordinary star charts and star finders: (1) no other tables are needed, (2) the planets, moon, and stars are on the same table, (3) true bearings and altitudes are not distorted, and (4) views for different latitudes and times are grouped together so that the appearance for intermediate latitudes and times can be visually interpolated.

The sky diagrams are arranged by months and are broken down into two-hour periods. Remember, the sky diagrams must be entered using Local Mean Time (LMT). To compute Local Mean Time at your position, you must convert your longitude to time. As an example, the Zulu time is 0900, and you are over the Pacific at 144°W. Converted to time, 144°W is $09^h36'$. This figure is subtracted from Zulu time for west longitude and added for east longitude to learn LMT thus:

0900Z
2400 (+24 hours, if necessary)
3300
—0936 (144°W converted to time)
2324 LMT

With the LMT at your position, you can now select the proper diagram.

There are two sets of diagrams. The first set, the one I'm concerned with here, is further broken down in latitudes from 30° south to 70° north in 20° increments, and is provided for sub-Polar regions. The other set of diagrams, for Polar regions, works basically the same way.

In each diagram the outer circle is the horizon and the cross in the center of the observer's zenith. Each of the smaller circles represents 60°, and the cross, 90° (overhead). Azimuths are referenced to True North, with 360° at the top. Some diagrams have small curved arrows indicating diurnal motion, the motion in one hour being represented by the length of the arrow.

One important point to keep in mind is that although the charts depict sky appearance on the 15th of the month, they can serve for the whole month. To adjust for motion of stars and planets during the month, add one hour to that shown on the diagram for the beginning of the month or subtract one hour for the end of the month. When Venus or other bodies move considerably in a month with respect to the stars, the diagrams will show positions for the first and last of the month, the first of the month being the position further west.

The moon, which is shown as an encircled number, moves so rapidly with respect to the stars that its position will vary greatly from night to night. To allow for this, the moon is shown for three of four different dates and you can interpolate for the intermediate dates.

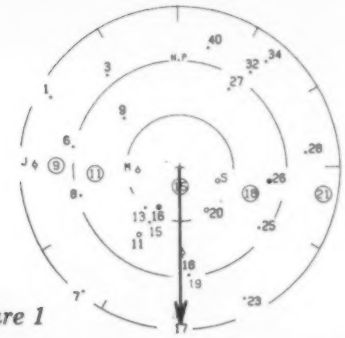


Figure 1

As an example, let us select the best available object to give a two body fix at 2300 LMT on 10 January 1976 during a flight on true course/track 180° at latitude 30° North. The required diagram is reproduced in Figure 1 from the Air Almanac 1976 January—April, with the course/track 180° on it. Examination of the diagram shows immediately that the best objects, giving position lines perpendicular and parallel to the track, are bodies numbered 18 and 26, Sirius and Regulus (see the star index on page F4 of the Almanac). Sirius has an altitude of about 33° and a true bearing of about 180°. Regulus has an altitude of about 32° and a true bearing of about 95°.

As a second example, let us suppose that on 1 February 1976 2200 LMT at a latitude of 30° North, you need to know what bodies are available. As we stated before, the diagrams are built for the 15th of the month, adjusting for actual date by adding one hour for the first of the month or subtracting one hour for the end of the month; therefore, the diagram for 15 January 2300 can be used for 1 February 2200.

It is necessary to remember that the diagrams were made to be used flat on the chart table with North at the top and that bearings are in true. For some intermediate latitude, such as 40°, or for an intermediate time, such as 0400, altitudes and bearings may be interpolated, but such accuracy is unnecessary to achieve body identification.

In the future when you only have one or two celestial bodies with which to obtain a fix and you can't determine visually their identity, go to the sky diagrams in your Almanac. It could save your next nav leg.

Capt St Pierre is a graduate of Nicholls State University, in Louisiana. He graduated from navigator training at Mather AFB in September 1973. Capt St Pierre has been stationed at Altus AFB since completing KC-135 combat crew training.

DEATH OF THE H-CUT

Captain Gary C. EICKMEIER
71 AREFS
Barksdale AFB, LA

There has been a slight change in the way to teach celestial fix resolution at Mather. The H-cut has taken a fall. At least, the way to teach *resolving* an H-cut fix has changed.

Briefly, the "company policy" on H-cut fix resolution was to assume a constant error in all the LOPs, and find a fixpoint that results from moving all the LOPs the same amount, and in the same *direction* (toward or away from the body). This resulted in the placement of the fix outside the triangle formed by a modified (triangular) H-cut.

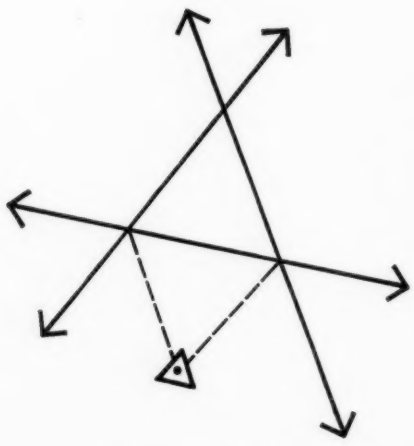
I had misgivings about the assumptions that are made with this sort of fix placement, and so I suggested that we eliminate H-cut fix resolving procedures which cause us to place the fixpoint outside the triangle formed by the LOPs. The reasons are:

a. The fix is farther from all the LOPs than if it were placed in the center of the triangle.

b. This procedure assumes all errors are consistent in both magnitude and direction (sign). My experience has been that this is not true most of the time, especially in modern jet aircraft. Some of the LOPs are too high and some are too low. This would make the most probable position to the center of the triangle, not the outside.

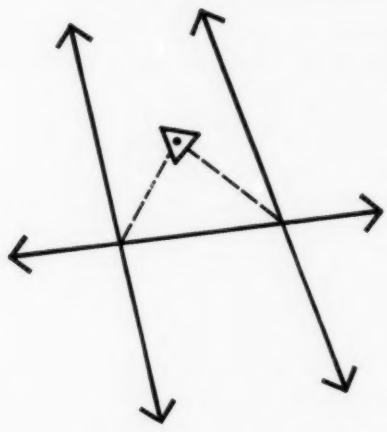
c. With a known good sextant, or a good sextant correction, there is no reason to ever place the fixpoint outside the triangle. In other words, there is no reason to assume a *further* error other than the random error that caused the triangle.

d. AFM 51-40, on page 14-13, says that unless there is reason to deviate from this procedure,



Modified H-Cut

All LOPs moved away by the same amount.



Classic H-Cut

All LOPs moved toward by the same amount.

common practice dictates that we should take the center of the figure formed for our fixpoint. By "center" they mean the point representing the least total error of all lines considered reliable.

e. ***Navigation*** magazine, the journal of the Institute of Navigation, had a Navy study in volume 19, number 4, called "Celestial Fix - Internal or External?" that proved experimentally that the internal fix was more accurate than the external fix.

The feeling for eliminating present teaching on H-cut fix resolution is becoming increasingly popular among celestial instructors and other interested officers. H-cut theory presently makes several unfounded assumptions that force the fix to be placed outside the figure formed by the LOPs, and could lead to navigational error if followed blindly. Several fix examples can be drawn which reduce H-cut fix resolution to absurdity. The fixpoint would be many times farther from the LOPs than if the fix were simply placed in the center of the triangle. In addition to the reasons already stated, common sense dictates that if the sextant is good or a good sextant error is applied, celestial LOPs are no different than any other lines of position and should be taken at face value, and the fix placed in the center of the figure formed.

The only question that remained was the possibility that if you *did* get a bad sextant once in a while, and if you didn't know that it was bad, would it be statistically safer to use the H-cut technique? Can the sextant error be cancelled by employing these resolving methods? Or would it be safer to just use the center for all fixes? I conducted a flight test of approximately 25 H-cuts to determine which method of fix resolution would be correct more often. I used both students and instructors, both classic and modified H-cuts, and shot these fixes from all sides of the aircraft. A radar fix was taken at fix time and the two fix resolutions were compared with the actual position of the aircraft. Nineteen of the 25 fixes were usable (shot all the proper stars), and the results were:

a. Nine fixes were indeterminate (pinpoints or neither one closer than the other).

b. In the cases where it did make a difference where the fix was placed, six of them supported placement in the center, and only four fixes were closer to the H-cut position.

I was more impressed with the randomness of the shots than I was with the final statistics, both of which support my contention. If the errors that cause the LOPs to form a triangle instead of a pinpoint are more random than constant, then the center of the figure is the most reasonable choice for the fixpoint.

In addition to the above test, I monitored a night celestial racks instruction unit in which the students are directed to shoot an H-cut as their last fix. Of the students who obtained three good shots, I found only one example which showed the H-cut position to be closer to Mather than the center of the triangle, and that was only if the student did not apply his already known sextant correction. Seven supported the center of the triangle, and two were pinpoints.

Experienced navigators know that fix resolution is a matter of judgment, weighing the DR, and many other factors to arrive at the most probable position. But if a policy on fix resolution is to be taught, I believe this is the most correct and prudent line to follow—a reasonable attempt should be made to determine a sextant correction, if any, and then, no matter what kind of fix is shot, place the fixpoint in the center of the figure. Sextant error is important in an H-cut situation, but an H-cut cannot give you a sextant correction!

The Mather Instructor Guide explains: With a "normal" fix, the bodies are all around the aircraft and any unknown constant sextant error would be self-cancelling because the position of the center of the triangle would not change if you moved all the LOPs towards or away from the bodies. But with an H-cut, the bodies are all on one side of the sky; in fact, with a modified (triangular) H-cut, the stars encompass only 120° or one-third of the sky. In this situation, the LOPs would act more like a single LOP, "pulling" the fix to one side or another if there was some constant sextant error.

The point is that the H-cut is less certain than the normal type of fix, so you should avoid shooting an H-cut whenever possible.

Capt Eickmeier received a BFA in Industrial Design from Wayne State University, Detroit, followed by OTS commission in 1968. After UNT graduation in 1969, he was assigned to the KC-135 at Westover. In 1973, he served at Mather AFB as a Celestial Instructor and then as a Curriculum Liaison Officer. Capt Eickmeier now is an instructor with the 71 AREFS, Barksdale. He is a previous contributor to THE NAVIGATOR.

Training the Electronic Warfare Officers

Major Jerome G. GINGER
453 FTS
Mather AFB, CA

Situated on the eastern edge of the business section of Mather Air Force Base, California, is Armond Hall, home of the 453d Flying Training Squadron, whose mission is to train Electronic Warfare Officers (EWOs). Unfortunately, a beautiful, unobstructed view of the Sierra Nevadas cannot be seen from within as the building is windowless and surrounded by an eight foot high barbed wire cyclone fence. Exactly what sort of clandestine training transpires inside? Before discussing the training, for a moment let us digress.

You have often heard the old axiom, "The best defense is a good offense." On the football field that might be a viable strategy, but in today's sophisticated airborne environment, if the defense hasn't done its homework, you may not get an opportunity to display that offense. In the air-to-air, air-to-ground battlefield, the defense will consist mainly of Electronic Warfare techniques. These techniques are many, varied, complex and growing. In December 1972, Electronic Warfare success was achieved in the skies over North Vietnam. A very low loss rate was experienced despite the heavy surface-to-air missiles (SAMs) and antiaircraft artillery (AAA) fire employed by the air defense system. Yet some months later, a much improved air defense system was seen in the October 1973 Middle East conflict. Since then the momentum and thrust directed towards Electronic Warfare efforts have gained considerably in both stature and importance.

Before progressing any further, let me pose a few questions. In this dynamic, challenging, and rapidly changing field, how do we define Electronic Warfare? What background is necessary for a typical Electronic Warfare Officer trainee? What types of courses are required? Is there follow-on training? And, finally, is training restricted to Air Force officers?

The all-encompassing definition states that Electronic Warfare is military action involving the use of electromagnetic energy to determine, exploit, reduce, or prevent hostile use of the electromagnetic spectrum and action which retains its friendly use.

This definition is broken down into its component parts in the 453d Flying Training Squadron—the nucleus of training for all US Air Force officers who enter the airborne Electronic Warfare field. The specialty qualifications, in accordance with Air Force Regulation 36-1, state that a bachelor of science degree is desirable with appropriate courses in physical sciences, engineering, mathematics, administration, and management. More often than not, however, most students entering the program have less technical backgrounds. In fact, a Squadron Operations Officer once stated that the only personnel having an advantage in getting through the school are theology majors. A second qualification is that Air Force personnel must be graduates of USAF Undergraduate Navigator Training. However, US Marine Corps personnel also attend this course and receive the same training as their Air Force counterparts.

Superior instruction is provided by 60 instructors who are well versed in their respective specialties. The average platform instructor has

Armond Hall

flown numerous combat missions in such varied aircraft as the F-4, F-105, B-52, EB-57, EB-66, EC-121, C-130, AC-130, DC-130, E/RC- 135, and F-111.

The school length has been trimmed to 96 training days or approximately five months. The present curriculum is broken down into roughly four phases. Initially, for five weeks, the student learns the basics of Electronic Fundamentals. Emphasis is now placed on general concepts rather than the complicated circuit diagrams. As electronic equipment has become more complex over the years, the possibility of effecting airborne repairs to malfunctioning equipment has declined considerably. In this early phase, the student builds a practical vocabulary of electronic terms, examines the mechanisms of various types of receivers, and masters the inner workings of a radar set. Other topics covered range from basic circuit analysis, principles of infrared and electro-optical devices to computer principles and electronic counter-countermeasures (ECCM).

The next six-week phase covers both friendly and hostile electronic support measures (ESM) which is primarily an information producing, intelligence gathering activity. In this phase, the student learns the various techniques for compiling information associated with both friendly and hostile radars. Every piece of equipment or radar site which radiates electromagnetic energy has certain characteristics which are as identifiable as a fingerprint. These emanations can be intercepted, recorded, and then critical information deduced such as frequency, emitter angle of arrival, pulse width, pulse repetition frequency, scan characteristics, and polarization. Thus, ESM provides a groundwork of electronic warfare information required to conduct electronic countermeasures (ECM), ECCM, and threat detection for radar warning, avoidance, or homing. This information is then consolidated in a publication called the Electronic Order of Battle. Throughout the training program, students learn to use a variety of sophisticated equipment including pulse analyzers, receivers, transmitters and expendable systems (chaff/flares). During the ESM phase, the student gets his first exposure to a device called the AN/ALQ-T5, affectionately (?) and coincidentally nicknamed "Hal."

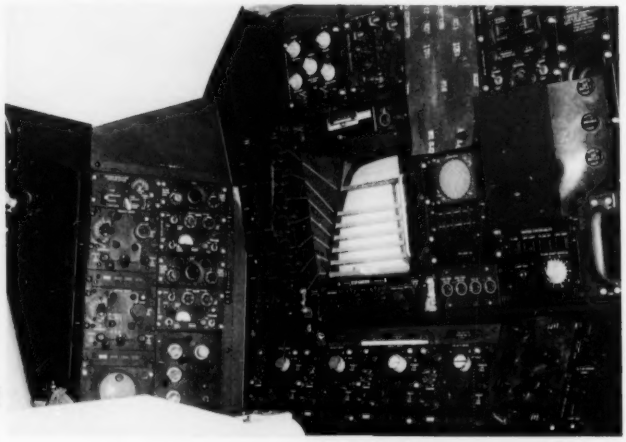
The AN/ALQ-T5 is a modern multimillion dollar Electronic Warfare simulator controlled by a general purpose digital computer. The T5 provides individual monitoring and grading for up to eight students simultaneously. Each student can fly an independent mission and receive instantaneous feedback on his errors, with reinstruction in his problem areas. The T5 flies all basic types of electronic warfare missions. The gaming area is 2,000 nautical miles by 2,000 nautical miles, and the T5 can fly at simulated speeds and altitudes up to 2,000 knots and 100,000 feet, respectively. Thus, these parameters can easily fall into the envelope characteristics of fighter, bomber, or reconnaissance aircraft.

T5 Instructor Console

By now the student is proficient in gathering information through the Reconnaissance phase. The Penetration Systems phase offers one of the possible practical uses of this information. Probably the greatest problem facing an Electronic Warfare Officer is how to protect his aircraft while negotiating an enemy air defense system. This three-week phase of training attacks that problem. ECM encompasses all action taken to nullify the effective operation of enemy electromagnetic systems and includes both jamming and deception techniques. The enemy must not gain any useful information from his defensive network. The methods to be utilized can include degrading, saturating or destroying the enemy system, or portions of its key components. A radar's receiver is extremely sensitive, and electronic jamming takes advantage of this fact. From the intelligence gathering effort, the student now is able to match his jammer output frequency with that of the radar receiver and introduce electromagnetic energy, commonly called deception or noise jamming, into the enemy's radar circuitry. On a strategic aircraft, such as the B-52, the Electronic Warfare Officer has receivers, jammers, and expendables at his disposal. His receivers enable him to detect all radars that are illuminating the aircraft. He then

judiciously determines which radars present threats to his aircraft and applies the appropriate countermeasures against them. The student receives much of his Penetration Systems training in the ALQ-T4 simulator. Although not as sophisticated as the T5, it provides comprehensive ECM training in a B-52 ECM cockpit environment by simultaneously displaying numerous simulated radar threats for the EW officer to counter. Procedures learned in the T4 have proven invaluable not only in regards to ECM but also in the areas of communications and crew coordination.

T4 Simulator



A natural follow-on to Penetration Systems is a two-week course in Strike Support. The Penetration Systems training covers self-protection of your aircraft. In Strike Support, the EWO will lend assistance to nearby aircraft that will be conducting strike missions. As the target is approached or an orbit nearby taken up, the EW is busy compiling a list of hostile radars that are on the air. At a predetermined time in the mission scenario, the EW will activate his jammers against radars posing a threat to the strike force. Experience gained in Southeast Asia has irrevocably demonstrated that specialized ECM aircraft are extremely important when a number of strikes are in progress in a given area.

Permeating all of this training is the fact that Electronic Warfare requires split-second timing. Students are taught to react quickly to a variety of threats because a matter of seconds could equate to mission success or failure— life or death.

Perhaps the one phase of EW that hinges most on reaction time is Attack Systems. This two-week block of instruction delves deeply into the fabled role of the Wild Weasel. The Wild Weasel has an illustrious past reaching back to its inception in the mid-1960s with the F-100. Other Weasel aircraft have been the F-105F/G and F-4C. The Wild Weasel mission insures that friendly forces can operate over hostile territory free from the threat of radar controlled defenses. This is accomplished in basically two ways. In the hunter-killer role, the Wild Weasel aircraft tries to entice the enemy radar to come on the air, thereby electronically highlighting itself. The trick, then, is for the Weasel to expend his ordnance at the highlighted threat radar, before the threat radar can direct SAMs at the Weasel. The second role is that of suppression, whereby Wild Weasels accompany strike forces and provide them protection against threats as they present themselves whether they be SAMs, AAA, or airborne interceptors.

Interspersed throughout the curriculum is a phase of instruction entitled Special Applications. Here, the student must solve a hypothetical electronic warfare problem using the knowledge gained during the training program.

The foregoing briefly describes the current training in the 453d. However, Electronic Warfare is one of the most dynamic and vibrant fields in the Department of Defense. As such, changes occur on practically a daily basis. An entire course revision is now underway that will incorporate many of these latest changes.

One of the ways that these changes and needs are identified is through an entirely different course taught in the 453d. Six Electronic Warfare Refresher Training classes are held yearly. These classes are composed of Air Force personnel who are working in either staff or operational EW related positions. Although they are students for the week they are here, they bring a wealth of information with them which is shared with the other "pros" in their class. In addition to providing a forum for the exchange of information, ideas, and experience among experts, the course provides an update on electronic warfare within the DOD complex. The faculty of the 453d also benefits as they are kept aware of recent changes in equipment, tactics, etc.

The 453d also conducts a course four times yearly for US Army personnel. This five-day course is designed to familiarize attending Army personnel with the threat and electronic warfare equipment, concepts, planning, and exercises.

One of the least publicized, but also one of the most important courses taught at Armond Hall is the Electronic Warfare Operations/Staff Officer Course (Security Assistance Program). This ten-week course is designed for staff officers from NATO and other selected allied countries. This

training provides a basic expertise in electronic warfare operations/staff functions and in formulation and application of electronic warfare plans and programs.

This, then, summarizes the various courses taught in the Electronic Warfare curriculum in the 453d Flying Training Squadron. This Squadron realizes the need to stay abreast of the sweeping changes and innovations occurring daily in the friendly and adversary Electronic Warfare environment. In response to this need, instructors expand their knowledge by attending technical symposiums and conferences, and by reading publications pertinent to this career field. The 453d also takes advantage of information in related career specialties. In fact, five nonrated instructors presently serve on the faculty, bringing their expertise from the areas of communications, ECCM, and computer science.

Hopefully, this article will reduce some of the mystery surrounding Armond Hall and Electronic Warfare training in general. In addition, personnel in all areas may have gained an insight into the inner mechanisms of this dynamic career field.

Maj Ginger, a native of Waterbury, Connecticut, entered the Air Force in 1964 via OTS. He then served as an Avionics Maintenance Officer at Homestead AFB, Bien Hoa AB, and Ramstein AB. In 1970, he graduated from UNT and EWT, followed by assignment to Barksdale AFB, including four Arc Light tours. In 1975, he returned to the 453 EWT Squadron at Mather AFB. and now serves as a Flight Commander.

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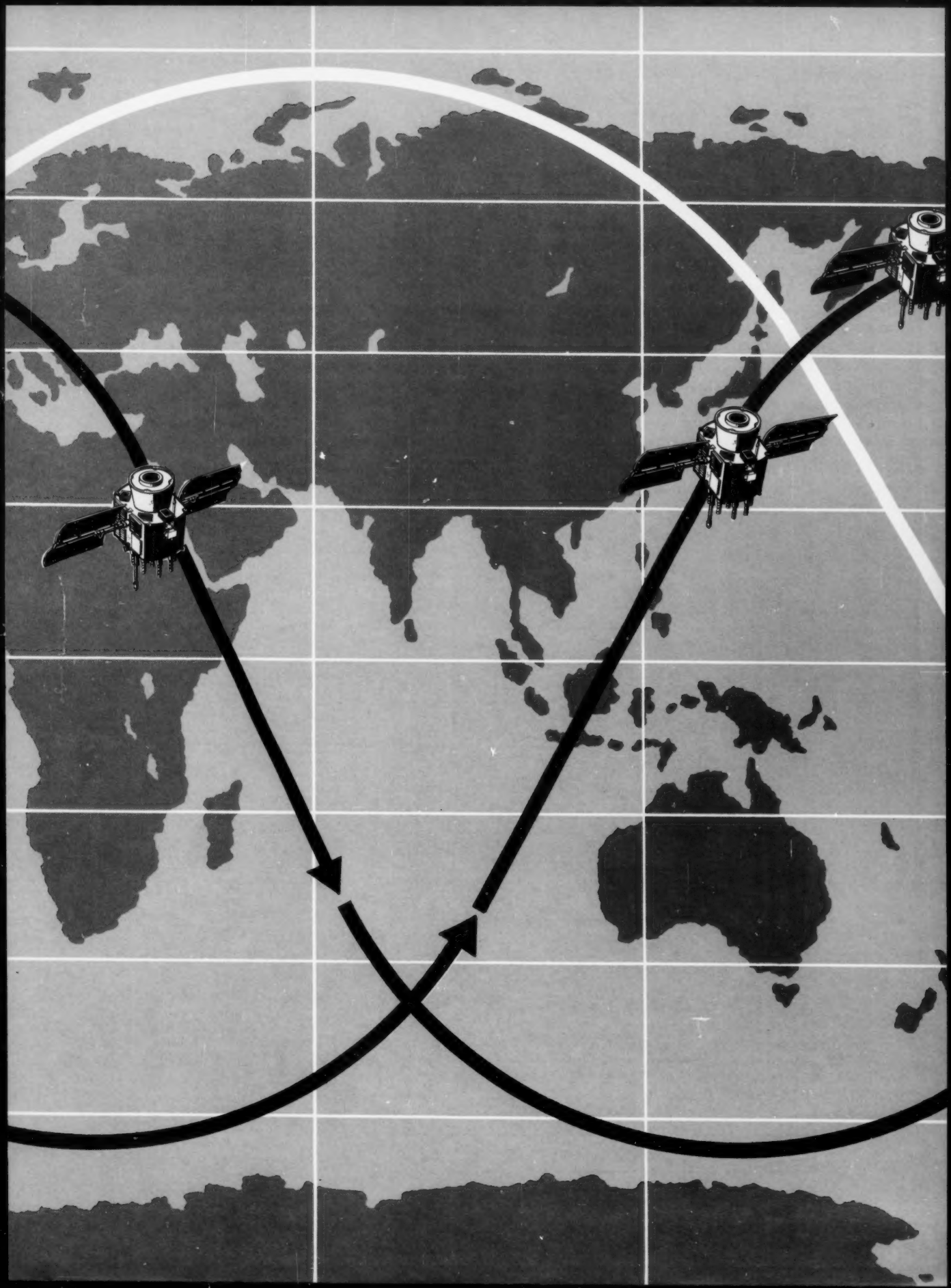
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